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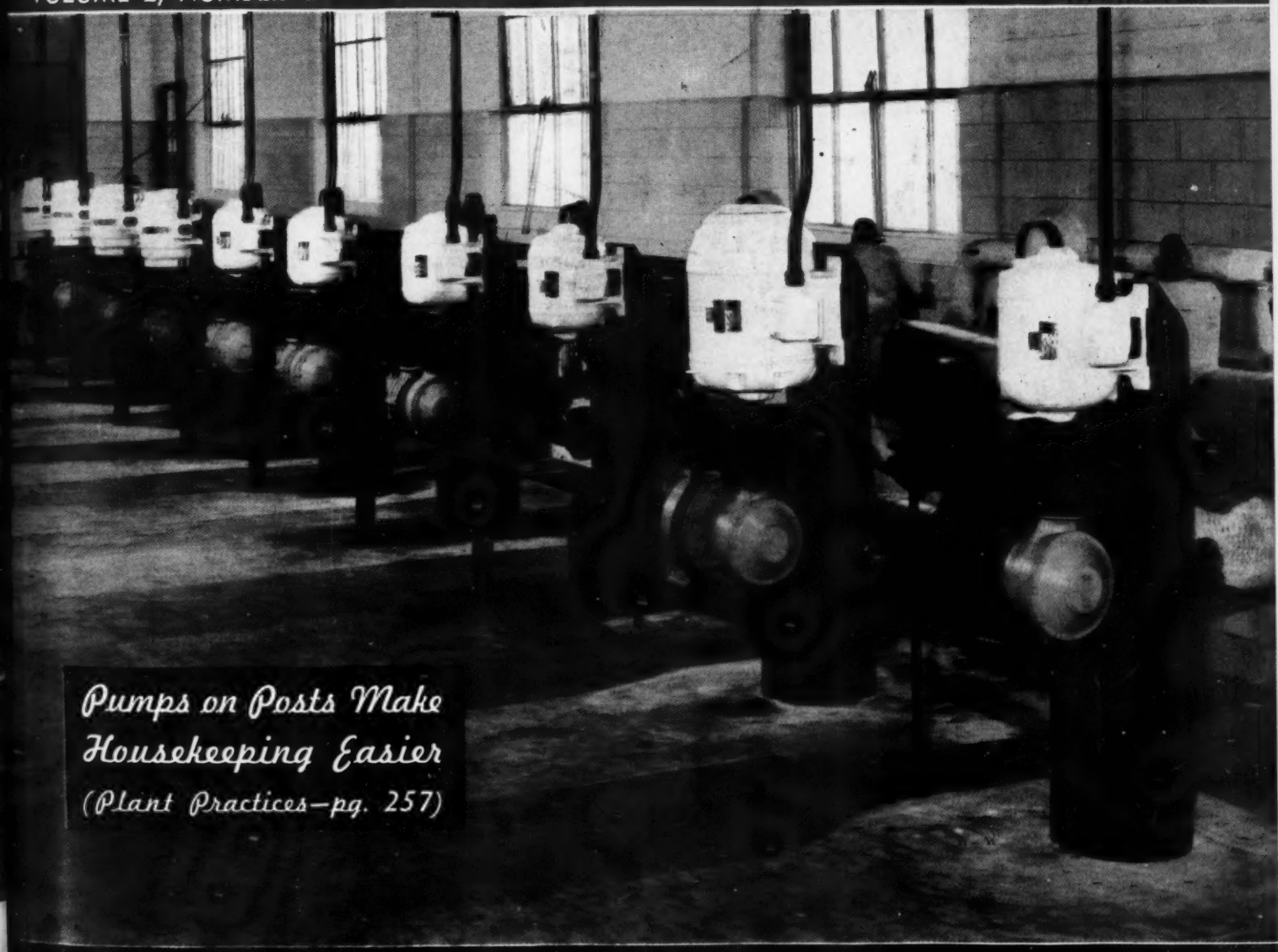

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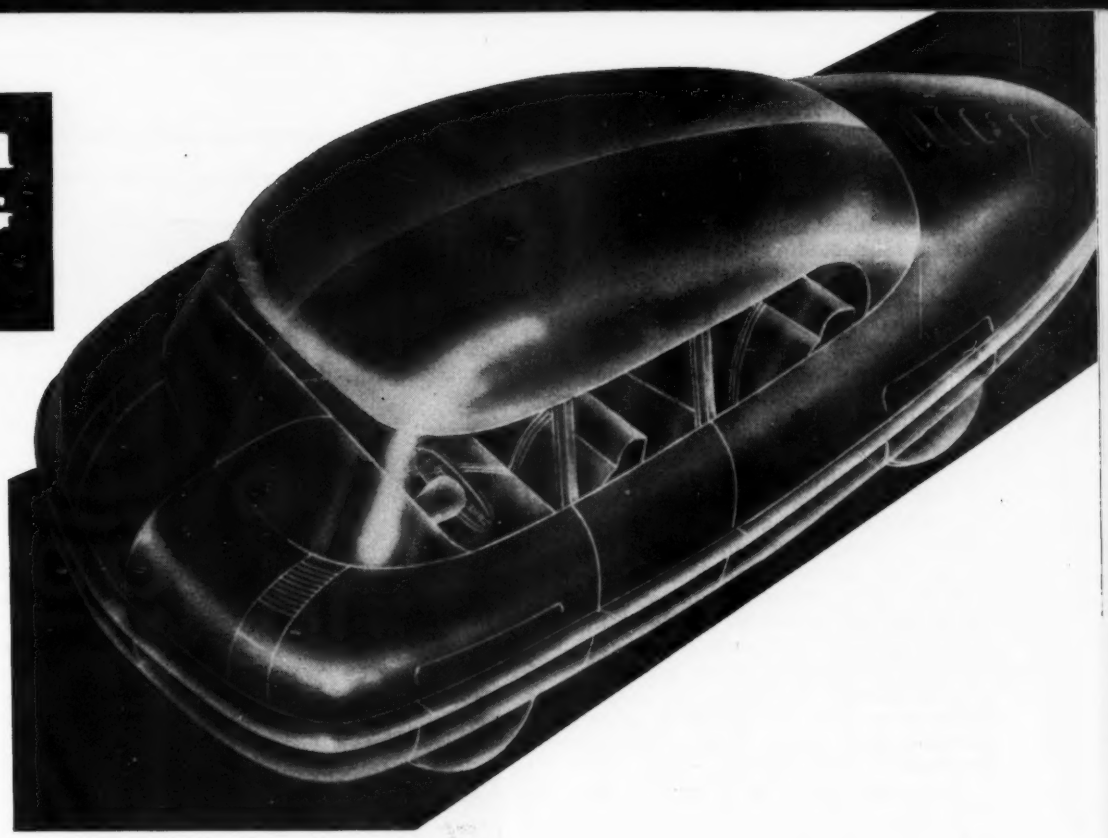


*Acme photo*

# What Next in Automotive Fuels?

*By DR. D. P. BARNARD*

*Associate Director of Research, Standard Oil Co. (Indiana)*

**Important quality changes which may be expected in a few years in the principal petroleum fuels are presented in the light of wartime and postwar developments to date:**

**MOTOR GASOLINES with ASTM octane ratings as high as 87 (premium grade) may be fairly widely available within two years or so, because of increasing supplies of catalytically cracked naphtha.**

**AVIATION GASOLINES of higher quality than 115/145 can be made but will probably not be required in the near future.**

**HEATING and DIESEL OILS will come increasingly from cracked stocks and will have slightly lower hydrogen-carbon ratios; they will be satisfactory fuels but will require increased attention from the equipment standpoint.**

WARTIME achievements of modern industry and glowing promises of things to come in the postwar "dream world" have created understandable interest in the new developments in the field of petroleum technology.

During the war, speculation was rife as to the possibility of "100 octane" becoming available at the corner service station—once it was no longer needed by the Army and Navy. Now, one and a half years after V-J Day, much progress has been made by the petroleum industry toward improving its products and processes.

The purpose of this paper is to appraise the effects of those process developments which were a part of the war effort, plus those which have been made in the postwar period. A practical picture can be gained by considering the impact upon several representative petroleum products; namely, motor and aviation gasolines, domestic heating oils, and fuels for high output, automotive type diesel engines.

It is well known that the petroleum industry manufactures an extremely wide variety of products, literally ranging from lubricating oils for slide trombones to fuel for locomotives—to say nothing of the galaxy which includes pharmaceuticals, preservatives, candles and detergents. By and large, however, volatile liquid fuels constitute the biggest single output (gasoline nearly 50%, heavier distillates upward of 20%). The progress made by the industry, therefore, can best be gauged by a critical study of what is being done in the field of gasolines, plus the closely allied distillate fuel products—heating and diesel oils.

The following discussion presents the best information available in the form of answers to these questions:

1—What improvements have been predicted and what thus far have been accomplished?

2—What are the prospects for early further improvements?

3—What are the trends for the foreseeable future?

## *QUESTION 1— What's Been Predicted and What's Been Accomplished?*

On Dec. 2, 1943, Bruce K. Brown, then Assistant Deputy Administrator of PAW, and the writer presented a paper entitled "How Will the 100-Octane Aviation Gasoline Program Affect Motor Gasoline", before the Metropolitan Section of the Society of Automotive Engineers. In that paper every effort was made to appraise the probable effects of the wartime aviation gasoline program upon the octane number levels of postwar motor fuels.

It was pointed out that, under peacetime conditions, the amount of 100-octane gasoline which could be made within the acceptable limits of economics of crude utilization, and using the equipment of the War Emergency Program, would probably not be over

one fifth of the amount scheduled for the wartime program. The net result would be that immediately after the war, a substantial portion of our aviation gasoline manufacturing facilities would be discharged from war duty and those which could be economically operated would be turned to the manufacture of motor gasolines, under conditions chosen for economic, rather than maximum octane number.

These and other factors, the paper stated, indicated that, immediately after the war, the average ASTM octane level of motor gasoline might increase as much as 3 units over immediate prewar values, and that the majority of manufacturers would be able to offer house brand products around 80 ASTM octane number and premium products of say 85 ASTM octane number. It was also stated that it seemed probable that values higher than these would result in extravagent crude usage, which would not be tolerable in the postwar period.

The paper concluded by stating that these opinions should not be interpreted as indicating that 100-octane motor gasolines would *never* be feasible as an automobile fuel. Rather, it was felt that in the period immediately following the war, improvements such as those outlined would be definitely practical, with succeeding improvements possible, but requiring equipment design, development and construction.

### The Author

Dr. Daniel P. Barnard IV, Associate Director of Research, Standard Oil Co. (Indiana), for many years has followed closely both technological and economic developments in the manufacture and use of automotive fuels. He is a director and vice president of the Coordinating Research Council, and is also a member of the Subcommittee on Aircraft Fuels and Lubricants of N.A.C.A.

Dr. Barnard came to the Standard of Indiana as assistant director of research at the Whiting refinery in 1925 to establish its automotive engineering laboratory. Since 1938 he has been an associate director, being transferred to the company's general offices in 1945. Earlier he served in the research laboratory of Massachusetts Institute of Technology, where he earned his M.S. and D.S. degrees.

#### Avgas Consumption Down

The domestic production of 100-octane aviation gasoline dropped to but a small fraction of its peak of 525,000 b/d. As was expected, the airlines are going to the extensive use of grade 100/130. For the year 1946, the domestic airlines used approximately 15,500 b/d of grade 91/98 and 100/130 combined. Other civil operations, mostly non-scheduled transport and flight training, account for approximately 6000 b/d which adds up to a total of 21,500 bbls. This can be compared with the 30,000 b/d predicted in 1943.

As to quality advances since the war, it is now well known that a grade higher than 100/130, namely 115/145, has been under development for several years. The Standard Oil Co. of Indiana prepared the first large batch of 33-R reference fuel, which was very carefully made to the low edge of the specifications. Apparently, several airlines are expecting soon to receive transport equipment which will require 115/145 grade fuel. However, the quantity to be so used will probably remain small for some time to come.

A peculiar development in aviation fuels used in smaller private-type aircraft is that an unleaded fuel of 80 octane number has virtually superseded leaded gasolines for the grades of less than 91 octane number.

Of those facilities employed in the manufacture of 100-octane gasoline during the war, only catalytic cracking and some alkylation have been used in the manufacture of postwar motor gasoline. Most of the other facilities have been found either too expensive or too wasteful of crude to be used under normal conditions.

#### Motor Fuel Octane Up

The Bureau of Mines survey of gasoline marketed throughout the country during the early part of the winter of 1945-46 showed average ASTM octane numbers of 81 and 76 for premium and regular grades, respectively. In some sections, however, individual brands achieved octane numbers of 85 and 80 and, in a few instances, even slightly higher. That these values have not been maintained is the direct result of the lead shortage, which necessitated the allocation of ethyl fluid, and the establishing by the Civilian Production Administration of a maximum knock rating of 78.5 ASTM octane number for leaded gasolines.

It is interesting to note that no loud huzzas were heard when levels of 85-octane number were achieved, nor were the complaints particularly violent when they were reduced to 78. In other words, it would appear that most vehicles currently in service are adequately cared for by fuels having ASTM octane numbers of 78, and that variations above this level are of little intrinsic importance.

#### Distillate Fuels Unchanged

In the field of disillate fuels, both for heating and diesel engine use, no particularly significant changes have yet occurred. Demands for these products have increased markedly, but have not yet quite caught up—at least on a national basis—to the amounts which can be made available. For the five years ending with 1940, gasoline sales rose an average of 7% a year, while distillate fuel sales rose 17% per year.

This increase in distillate fuel demand, together with the necessity for cracking more and more virgin distillate stocks to meet the increase in gasoline needs, has resulted in a significant decrease in the percentage of virgin stocks available for heating oils. As a result, the burning qualities of heating oils have been lowered somewhat, although not so seriously as to interfere with use in appropriate equipment. No particular change has transpired in the case of Diesel fuels, and virgin stocks have been available, as before, in the quantities required.

## QUESTION 2—
## What Are the Prospects for Early Improvements?

In the year and one half since the war, 13 additional catalytic cracking units have been built or are planned which will increase catalytically cracked gasoline capacity to the extent of 100,000 b/d. The effect of this increase upon the octane number picture will be modified somewhat by gasoline demand which has unexpectedly risen to more than 2,000,000 b/d. It now appears that the amount of catalytically cracked naphtha to be available to the industry in another year or two should amount to nearly 30% of the total gasoline. This, in turn, should enable the industry to furnish fuels averaging about 6 ASTM octane numbers above prewar levels.

This guess assumes, of course, that the same amount of lead will be used as formerly.

In view of the increasing interest in the "Research" method for knock rating

motor fuels, it is interesting to note that if this prediction is borne out, the premium grade fuels can be expected to have sensitivities of at least 6 to 8 octane numbers. In other words, their CFR Research octane numbers will be about that much higher than their ASTM values. On this basis, premium fuels having ASTM octane numbers as high as 87, and Research octane numbers above 90—perhaps as high as 95—may be fairly widely available within another few years.

### Fuels Ahead of Engines

Research knock ratings above 90 octane number, by and large, typify fuels significantly better than are required by the automobiles generally in use at this time. True, cars can be found which will knock on fuels of higher than 90 octane, but usually this will be found to be the result of maladjustment, with actual engine performance well below that which should be attainable with such octane numbers. In spite of the fact that most engines in service cannot deliver returns commensurate with fuel quality at these higher octane number levels, the trend to make such fuels available—in advance of possible new engine designs which may require them — is rather strongly developed. Last fall and winter, as has already been pointed out, premium fuels having octane numbers on the high side of 90 (Research) were sold rather extensively on the East and West coasts. The writer will be very much surprised if premium octane numbers do not in general exceed 90 Research by the time the automotive industry can deliver engines designed to use them efficiently.

Research octane numbers of 90 or more, for fuels having sensitivities of 10 units or less, will involve appreciable increases in manufacturing cost over current premium grade levels. Since the development of catalytic cracking, no economically sound new process capable of increasing the octane numbers of motor gasoline has been devised. The various manufacturing methods (other than catalytic cracking and alkylation) used in the 100-octane program are too costly or extravagant for general use in the motor fuel picture.

### No Avgas Changes Seen

As to aviation gasolines, it appears that the grades now in use, including grade 115/145, will be with us for quite a while to come. The military services are using grade 100/130 for general operation, plus grade 115/145 for special purposes. Of course, almost anything might change this picture over-night, but it would seem that for some time to come the equipment designers will have plenty to do before they have taken full advantage of the higher grade. Certainly, no marked changes can be anticipated at this time.

As to civil transport operations, the trend seems unmistakably toward the general use of 100/130, with grade 91/98 rather rapidly dropping out of the picture. Some specialized long range operations may be carried out with equipment requiring grade 115/145. It is rather doubtful, however, if the amount of this fuel to be so used in the next few years will be very great. Miscellaneous non-scheduled operations of executive and transport-type aircraft probably will continue to use grade 91/98 and 100/130.

No imminent changes are indicated for the small, unsupercharged engines used in personal type aircraft. Nonleaded 80-octane number fuel will probably be found most acceptable as long as private flying remains upon a hobby basis, to be indulged in by a very limited number of people.

Currently, and for the immediate future, the oil industry will undoubtedly have excess capacity for manufacturing all of the grades of aviation gasoline in use. Immediately prior to the war, the domestic airlines had worked up to a daily fuel requirement of about 8000 to 9000 b/d. In 1946, the domestic airlines used about 15,500 b/d, while non-scheduled operations took 4100 b/d and miscellaneous private flying 2000 b/d. The best guess that can be made for 1947 demands is given in Table 1.

### More Cracked Distillates in Store . .

The distillate fuels, domestic heating oils, high speed Diesel fuels, kerosine, etc., must still be regarded as secondary products of gasoline manufacture. Gasolines constitute nearly 50% of the industry's marketed products while distillates amount to a little less than 20%. This is true, even through the demands for such fuels have risen markedly during the last few years. Currently, the volume of distillate fuel used is only about 1/3 that of motor fuel, but its annual rate of growth is much faster than that of motor fuel. The outlook for continued expansion in distillate fuel sales can only mean that, as time goes on, distillate heating oils will contain increasing proportions of cracked stocks and therefore will show decreasing hydrogen-carbon ratios. It appears that they also must contain increasing amounts of sulfur because of the diminishing supply of the "sweet" crudes, and the necessary increase in the use of high sulphur "sour" crudes. There is no reason why such fuels cannot be stable and of satisfactory burning quality. However, as time goes on, the fuel available will be less able to forgive derelictions in design and maintenance of the burning equipment. This trend, it would seem, must apply to virtually all grades of distillate fuels—certainly to those which are used in the large quantities required for space heating.

### Diesel Fuels Due for Changes

Fuels for Diesel engines of the high output type seem due for some changes within the next year or two. The catalytic cracking unit requires virgin charge stocks for economical operation, and its demands for such stocks are increasing, with the result that competition with the Diesel engine for such stocks is becoming more and more intense. A possible solution is suggested in a recent SAE paper by Shoemaker and Gadebusch,* who show that the effects of lower octane number can be compensated, at least partially, by lowering the 90% point of the fuel. This paper, incidentally, points out that fuels having ratios of the 90% point (in degrees F.) to cetane number of not more than 13 to 1, show quite good burning characteristics in most engines. Certainly some solution to the high speed Diesel fuel problem must be found, if for no other reason than because of the railroad picture. Diesel fuels for railroad use are currently running about six times prewar demands. In addition, it seems that most of the railroads are endeavoring to convert to Diesel electric locomotives as soon as possible.

## QUESTION 3—
## What Are the Trends for the Forseeable Future?

When it comes to projecting the probable future of octane numbers for motor gasolines, it would be very nice to be able to draw curves which could be extended over 5, 10 or 15 years. Unfortunately, such a convenient approach to the problem is entirely impractical. What will happen in the more distant future is quite likely to be dictated by developments which at this time cannot be clearly foreseen. As has been pointed out, motor gasoline octane numbers much above 90 Research will be expensive to attain by any process now known. Further, to justify the additional manufacturing costs, they must be matched by appropriate engine developments.

### Drastic Engine Changes Seen

Rather drastic changes in power plant design are strongly indicated in order to take full advantage of the higher quality fuels already being distributed. The power plants now in general production are not very different in their basic designs from those of 10 and 15 years ago.

**TABLE 1—Estimated 1947 Demand for Aviation Gasolines**

| | Bbls./Day | Grade |
|---|---|---|
| Domestic Airlines (including trans-ocean operations) | 20,000 | 100/130 & 115/145 |
| Non-Scheduled Operations | 5,900 | 91/98 & 100/130 |
| Private and Training | 6,500 | 80 |

* F. G. Shoemaker and H. M. Gadebusch, "Effect of Fuel Properties on Diesel-Engine Performance", *SAE Journal*, July, 1946.

While automatic transmissions and fluid drives have come into the picture to some extent, most of the cars now being built, still employ the conventional friction clutch and transmission. Enough discussions have appeared in the technical press to indicate that, some day in the distant future, there will come into use automatic transmission (probably of several radically different types) and high compression power plants designed to deliver the goods (when used with such transmissions and when operated upon suitable fuels.)

Perhaps such power plants will justify more expensive fuels of higher octane number. In the past, however, the petroleum industry, of necessity, has taken the lead in making improved fuels available in advance of the requirements of high compression engines. The car builder has always had such fuels ahead of him and could redesign or modify his engines accordingly. By the same token, the user of older equipment could take advantage of such fuels as a means of avoiding the nuisance and expense of some maintenance work.

### Fuels May Become More Volatile

Whenever changes in motor fuel quality are discussed, thought is usually given only to octane number, although volatility characteristics constitute the most important distinguishing feature of gasolines. Perhaps, as the years roll on, motor gasolines will become more and more volatile, particularly with respect to end point, and may approach aviation gasolines more closely than they now do. No such trends are indicated at this time, however, for the good and sufficient reason that there are no indications that much better engine performance can be secured, although experience has demonstrated improved car operation, particularly with manual chokes, with fuels of higher than usual volatility.

Volatility characteristics of motor gasolines have become quite highly stabilized during the past decade or so, with 90% points not varying too far from 350°F., and front end volatilities adjusted to seasonal, geographic, and climatic changes. In all probability, front end volatilities will increase somewhat in the next few years, but the problem of vapor lock seems to impose a rather effective barrier to any changes in fuel volatility which would significantly increase tendancies toward vapor liberation at high atmospheric temperatures.

As time goes on, typical motor gasoline, like other fuels, will probably contain more and more sulfur. This is due to the increased use of "sour" crudes, as was pointed out in the preceding section of this paper. Processes exist by which the sulfur can be eliminated, or at least dropped to low levels. The cost of this operation, however, which would have to be borne by the purchaser of the finished product, would be considerable and, it would seem, cannot be justified by equipment or service requirements.

About 25 years ago, the necessity for maintaining low sulfur limits was established through experience with engine corrosion which in certain section of the country was quite severe. For many years past, however, all automotive engines have been built with positive crank case ventilation systems, which eliminate most, if not all, of the moisture. The result is that corrosion, even on fuels of comparatively high sulfur content, is much less severe than in the older engines with fuels of lower sulfur content. In fact, certain sections of the country have gotten along very well upon a diet of gasolines whose sulfur contents are several times those found to be tolerable more than 20 years ago.

### Avgas Components Won't Change

In spite of the fact that aviation requirements place very high premiums upon fuel quality, the use of fuels of more than 115/145 is not indicated in the near future. Better fuels can be made in quantity and some have actually been prepared for limited experimental use. As matters now stand, however, there appear to be virtually no prospects for either a new component, or for new manufacturing methods. In other words, as far as can be seen, aviation gasolines must be made from the strikingly small number of high octane components now available, most of which are in general use.

Up to this point, nothing has been said about fuels for the combustion turbine, or jet engine. These power plants, in spite of their prominence in military operations, must be regarded as in their early stages of technical development. Many aspects of these power plants have not yet crystallized, nor has development been carried to the point where fuel properties can be directly associated with performance. About all that can be said of the combustion turbine is that, to date, its fuel preference is remarkably similar to that of the high speed Diesel.

This combination, with other peculiar problems of utilization, has thus far indicated that aviation turbine fuels will closely resemble kerosine, high speed Diesel fuel, or mixtures of such fuels with gasoline. It is, therefore, impossible to offer any long range predictions concerning jet fuel developments at this time, and the writer will hazard the guess that several more years must pass before any pronounced trends in the characteristics of such fuels will become evident.

### Distillate Picture Is Uncertain

All things considered, the general distillate fuel picture is probably the most difficult to predict from a long range point of view. Current demands for domestic heating fuels amount to practically 1/3 the demand for gasoline. If they grow to 1/2 the demand for gasoline (and they very well might) there would seem to be no alternative than to make them of substantially all cracked stocks. This will, in turn, reduce their hydrogen-carbon ratio and to some extent make them still more critical to the various factors controlling combustion. Even if this should occur to the foreseeable extreme, however, such fuels should still be very good fuels. They can be made quite stable and combustible with good efficiency and reliability. They will, however, be *different* and will require that the furnace equipment in which they are burned be properly engineered to burn them satisfactorily and with clean, controlled combustion.

### Better Diesel Yardstick Needed

As for the Diesel fuel picture, it is somewhat technically complex but not necessarily pessimistic from the quality standpoint. A part of the problem, as far as the long range future is concerned, arises from the fact that the true needs of the high performance Diesel engine as used in railroad and highway transportation, are rather imperfectly known. Cetane number, as now measured, is far from a complete performance quality index. In many cases it seems to have functioned more as a cleanliness factor than as a criterion for ignition quality.

The necessary cleanliness and stability can and must be assured without the obligation to continue the use of virgin paraffinic stocks. To produce such fuels is, of course, the petroleum industry's responsibility. However, to use all the country's resources most effectively and to provide the abundance of fuels required by the multitude of Diesel engine users, *and at the lowest possible costs*, will require the cooperative efforts of all concerned, in order that the necessary compromises in adapting equipment to fuel requirements, and vice versa, can be effected. It now appears that the railroad uses for diesel fuel are heading rather rapidly to a demand of upwards of 10% of that of gasoline. This would seem to pose no serious problem although, as has already been pointed out, the quantities are so large as to require the careful adapting of equipment and fuels.

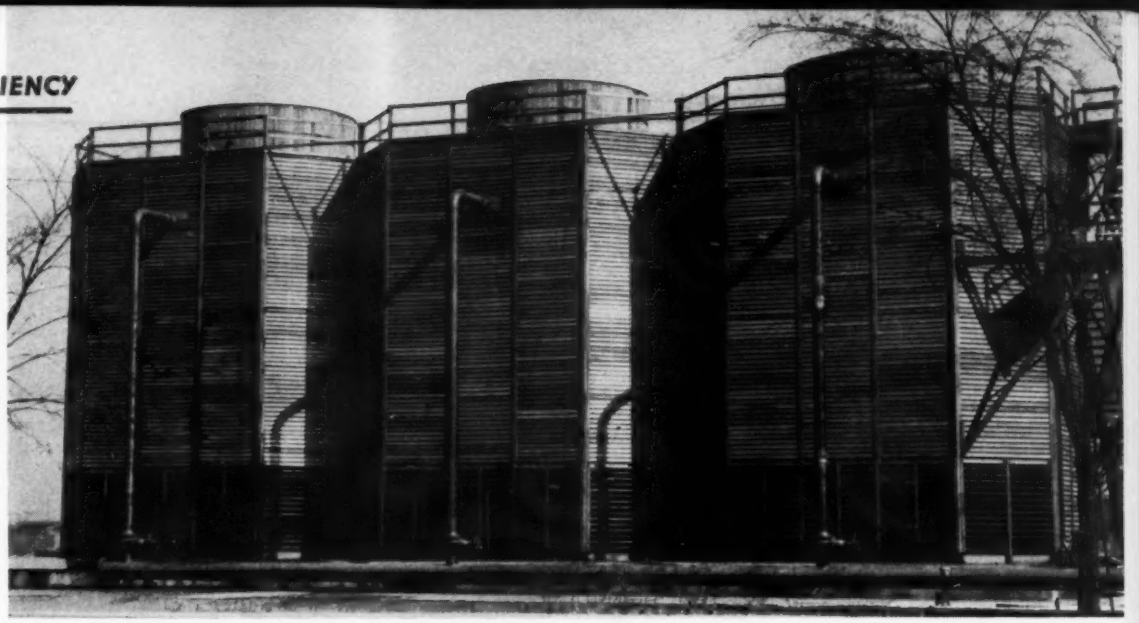
### Conclusions

This article is less a technical paper than a summary report on the quality changes which have recently occurred in the leading types of petroleum fuels and the further changes considered probable in the near future.

Perhaps the one fact most clearly indicated by this report is that the petroleum and automotive industries have entered the realm where the costs of further product quality improvement will increase at accelerating rates. Careful engineering of equipment and fuel will be required to insure resulting performances which will justify those cost increases to the ultimate user. Close co-ordination of development effort will be needed, and steps involving improvements in the products of either industry must be based on the most careful studies.

#### Acknowledgement

The preceding article is a slightly condensed version of a talk under the same title recently presented by Dr. Barnard before meetings of the Toledo Section of the A. C. S., the Chicago Section of the A. I. Ch. E., and the Peoria, Ill., Section of the S. A. E.



Typical installation of a three-cell, mechanical draft cooling tower. Circular domes at top of each cell contain fans for drawing air up through tower

# Evaluate Performance of Induced Draft Cooling for Closer Control of Costs

By JAMES G. DeFLON

*Chief Cooling Tower Development Engineer*
*The Fluor Corp. Ltd.*

**The closer control of production demanded in refineries today places more exacting demands upon cooling tower installations. In many instances each additional degree of cooling achieved means increased output and reduced plant operating costs.**

**Factors in the evaluation of cooling towers for efficient plant operation are presented in non-technical language. Tower performance is shown to be governed chiefly by the ratio of weights of air to water and the time of contact between water and air. Tower size is shown to be a function of the cooling range, quantity of water to be cooled, wet bulb temperature, air velocity and tower height. Performance curves are presented for preliminary estimations of design variables based on requirement variables. Examples are given to illustrate the use of the charts.**

**Discussion in this article is limited to induced or mechanical draft type cooling towers. A following article will discuss atmospheric type towers.**

THE processes of cooling water are among the oldest and simplest known to man. Some of the processes are slow, such as the cooling of water on the surface of a pond; others are comparatively fast, such as the spraying of water into air. These processes all involve the exposure of water surface to air with varying degrees of efficiency.

The heat transfer process involves a latent heat transfer due to change of state of a small portion of the water from liquid to vapor and a sensible heat transfer due to the difference in temperature of water and air. Approximately 1000 Btu are required to evaporate one pound of water. This is the amount of heat lost in cooling 100 lbs. of water 10° F. Therefore, for each 10° of cooling effected, roughly 1% of water is lost by evaporation. In addition, there will be a spray loss of not more than 0.2% in a well-designed atmospheric or mechanical draft tower. Water cooling from 120° to 90°, for example, will therefore lose 3.2% of its weight with each passage through the tower.

In cooling towers in which the water is warmer than the air, the heat removed from the water and transferred to the air $q_t$ is the sum of the sensible heat, $q_s$, and the latent heat of evaporation, $wr$. The sensible heat is small compared to the latent heat transferred.

$$q_t = q_s + wr$$
$$w = kA\Delta p_m$$

The factors which influence the performance of a cooling tower are therefore those which affect the expression $kA\Delta p_m$. The value $kA$ depends on the construction of the equipment, the extent of water surface exposed through drop surface and filming surface, and the velocity of the air. $\Delta p_m$ depends on the temperature of the water and the temperature and humidity of the air. Actually, $\Delta p_m$ represents the difference in vapor pressure between the water at its temperature and the water if it were at the wet bulb temperature of the air.

It is evident from the above that the water cannot be cooled below the wet bulb temperature of the entering air. The wet bulb temperature, or to be more precise, the adiabatic saturation temperature, represents the minimum temperature that the water would reach with infinite time of contact between water and air in a cooling tower. This must be kept in mind when designing a plant to operate on cooling tower water.

There are two types of cooling towers in general use today—the atmospheric and the mechanical draft. The older apparatuses for cooling water, i.e., the spray pond and natural draft chimney towers, have been almost exclusively replaced by those two types. The objection to the spray pond is the limited performance available and the nuisance created by the high water loss occurring during certain

seasons of the year. The objection to the natural draft tower is the high initial cost and the serious reduction in performance experienced during periods of hot weather.

Both the atmospheric and the mechanical draft towers are capable of cooling water to the same minimum temperatures. The economic situation, the prevailing atmospheric conditions, the desired approach to the wet bulb temperature, and the amount of space available, will indicate which type to select.

### Mechanical Draft Towers

Two types of mechanical draft towers are in use today. In the forced draft tower, the fan is mounted at its base and the air is forced in the bottom and discharged through the top at low velocity.

In the induced draft tower, the fan is mounted on the roof of the structure and air is pulled upward and discharged at a high velocity.

The forced-draft type is fast losing favor as it is more often subjected to the recirculation of the hot humid exhaust vapors back into the air intakes than the induced-draft type. This occurs under certain atmospheric conditions because the velocity of the humid exhaust air is so low that the suction created by the fans tends to draw it back into the tower. Since the wet bulb temperature of the exhaust air is considerably above that of the ambient air, there is a decrease in performance evidenced by an increase in cold water temperature.

Except for the location of the fans, the structural and operational features of the two types of mechanical draft towers are essentially the same. A cross-sectional view of the induced-draft tower with the various parts labeled is shown in Fig. 1.

The entrained moisture is removed from the exhaust air by the drift eliminator, which is placed just above the spray chamber and below the fan. The water is pumped to the main header located in the top of the tower where it is distributed to the various nozzles. This water is sprayed up in a manner similar to that used in a spray pond and is intimately mixed with the exhaust air before dropping to the docks below. (In performance, the upspray distributing system represents the equivalent of adding 8 or 9 ft. to the height of the cooling tower over that of the gravity-type system).

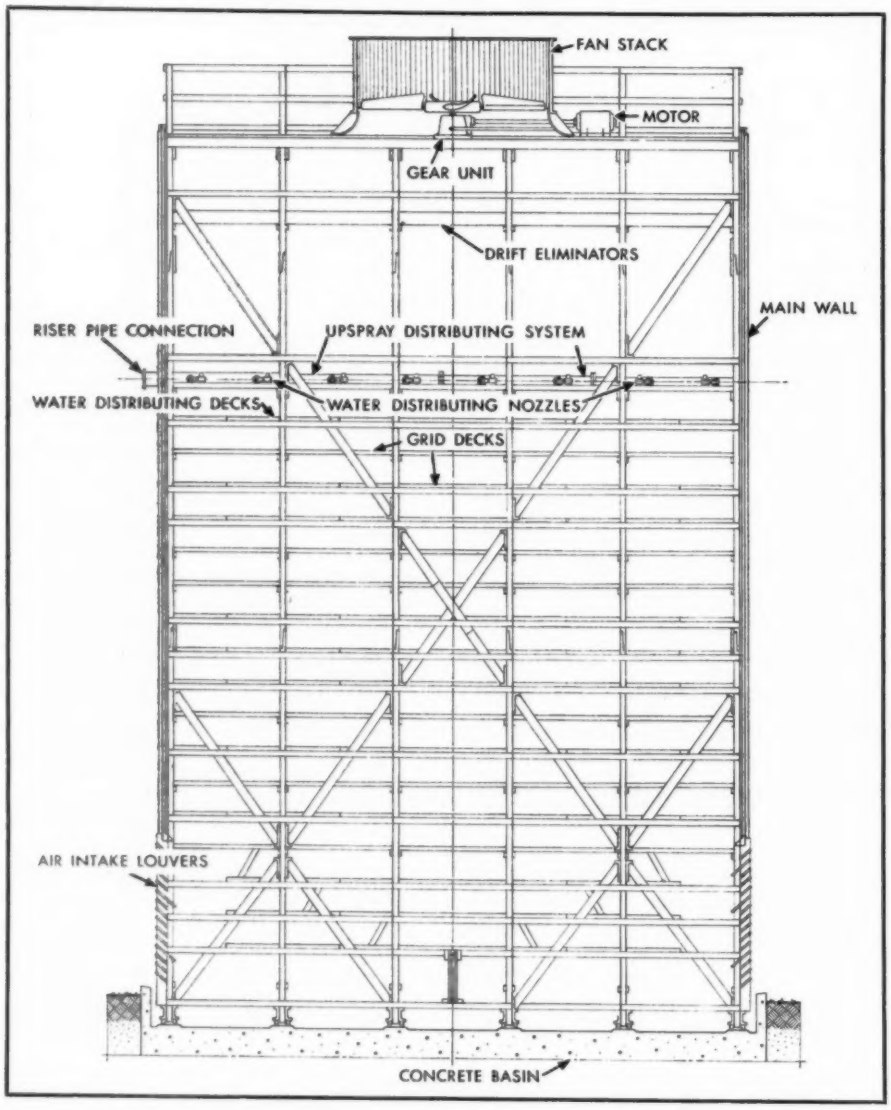



**Fig. 1—Cross-sectional view of a mechanical draft (induced-draft) cooling tower. With the upspray distributing system, it is necessary to allow sufficient space between the drift eliminators and the nozzles for a spray chamber**

The fall of the water is interrupted by the slat-type grids as it flows countercurrently to the air. In flowing countercurrently, the coldest water contacts the driest air and the warmest water contacts the most humid air. Maximum performance is thus obtained since the temperature of all of the cold water is approaching the wet bulb temperature of the entering dry air. This was not true of the older cross-flow and parallel-flow type cooling towers.

The performance of a given type cooling tower is governed by the ratio of the weights of air to water and the time of contact between water and air. In commercial practice, the variation in the ratio of air to water is first obtained by keeping the air velocity constant at about 350 ft./min./sq. ft. of active tower area and varying the water concentration (gals./min./sq. ft. of tower area).

As a secondary operation, the air velocity is varied to make the tower accommodate the cooling requirement. The time of contact between water and air is governed largely by the time required for the water to discharge from the nozzles and fall through the tower to the basin. The time of contact is, therefore, obtained in a given type of unit by varying the height of the tower. Should the time of contact be insufficient, no amount of increase in the ratio of air to water will produce the desired cooling.

It is therefore necessary that a certain minimum height of cooling tower be maintained. Where a wide approach* of 15° to 20° F. to the wet bulb temperature and a 25° to 35° F. cooling range** is required, a relatively low cooling tower will suffice. A tower in which the water travels 15 to 20 ft. from the distributing system to the basin is sufficient.

Where a moderate approach of 8° to 15° and a cooling range of 25° to 35° is required, a tower in which the water travels 25 ft. to 30 ft. is adequate. Where a close approach of 4° to 8°, with a 25° to 35° cooling range is required, a tower in which the water travels from 35 ft. to 40 ft. is required. It is usually not economical to design a cooling tower with an approach of less than 4°, but it can be satisfactorily accomplished with a tower in which the water travels 35 to 40 ft.

Fig. 2 shows the relationship of the hot water, cold water and wet bulb temperatures to the water concentration. From this, the minimum area required for a

* The approach is the difference between the cold water temperature and the wet bulb temperature.

** The cooling range is the difference between the hot water temperature and the cold water temperature.

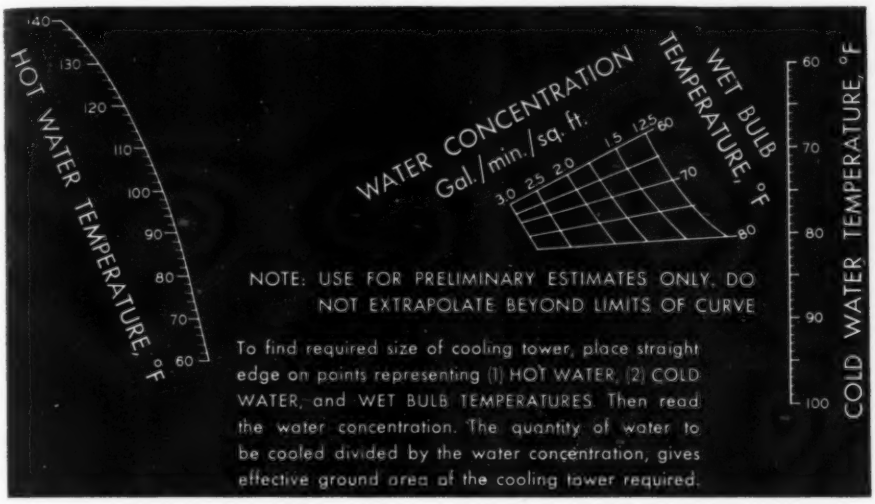



**Fig. 2—Performance curve of a counter flow, induced-draft cooling tower with up-spray distributing system containing 24 ft. of filling**

given performance of a well-designed counterflow induced draft cooling tower can be obtained. Fig. 3 gives the HP per sq. ft. of tower area required for a given performance.

These curves do not apply to parallel or cross-flow cooling since these processes are not as efficient as the counterflow process. Also they do not apply where the approach to the cold water temperature is less than 5° F. These charts should be considered approximate and for preliminary estimates only. Many factors not shown in the graphs must be included in the computation and hence the manufacturer should be contacted for final design recommendations.

### Performance Varies with Concentration

The cooling performance of any tower containing a given depth of filling varies with the water concentration. It has been found that the maximum contact and performance is obtained with a tower having a water concentration of 2 to 3 gals. of water/min./sq. ft of ground area.

Thus, the problem of calculating the size of a cooling tower becomes one of determining the proper concentration of water required to obtain the desired results. A higher tower will be required if the water concentration falls below 1.6 gals./sq. ft. Should the water concentration exceed 3 gals./sq. ft., a lower cooling tower may be used.

Once the necessary water concentration is obtained, the tower area can be calculated by dividing the gpm. circulated by the water concentration (gals./sq. ft.). The required tower size then is a function of the following:

1. Cooling range (hot water temperature minus cold water temperature).
2. Approach to wet bulb temperature (cold water temperature minus wet bulb temperature).
3. Quantity of water to be cooled.
4. Wet bulb temperature.
5. Air velocity through the cell.
6. Tower height.

To illustrate the use of the charts let us assume that we have the following cooling conditions:

| | |
|---|---|
| Hot water temperature .... | 102° F. |
| Cold water temperature .... | 78° F. |
| Wet bulb temperature (Twb) | 70° F. |
| Circulation ..... | 2000 gpm |

Laying a straight edge across Fig. 2 and connecting the points representing the design water and wet bulb temperatures, we find that a water concentration of 2 gals./sq. ft. is required. Dividing the quantity of water circulated by the water concentration, we find that the theoretical area of the tower is 1000 sq. ft.

To obtain the theoretical fan horsepower, we use Fig. 3. Connecting the points representing the 100% of standard tower performance with the turning point, we find that it will require .041 HP/sq. ft. of actual effective tower area. Multiplying by the tower area of 1000 sq. ft., we find that it requires 41.0 fan horsepower to perform the necessary cooling.

Suppose that the commercial tower size is such that the actual tower area is 910 sq. ft. We can still obtain the cooling equivalent to 1000 sq. ft. of standard tower area by increasing the air velocity through the tower. Within reasonable limits, the shortage of actual area can be compensated for by an increase in air velocity through the tower which, in turn, requires a higher fan horsepower. Our problem then becomes one of increasing the performance of the smaller tower by 10%. From Fig. 3, by connecting the points representing 110% of standard tower performance and the turning point, the fan horsepower is found to be .057 HP/sq. ft. of actual tower area, or .057 × 910 = 51.9 HP.

### Comparative Sizes

On the other hand, suppose the commercial tower size is such that the actual tower is 1110 sq. ft., the cooling equivalent to 1000 sq. ft. of standard tower area can be accomplished with less air and less fan horsepower. By the use of Fig. 3, the theoretical fan horsepower for a tower doing only 90% of standard performance is found to be .031 per sq. ft. of actual tower area or 34.5 HP.

This illustrates how sensitive the fan horsepower is to small changes in tower area. The importance of designing a tower which is slightly oversize in ground area becomes immediately apparent.

Let's assume that we have the same cooling range and approach as used in the first example, except that the wet bulb

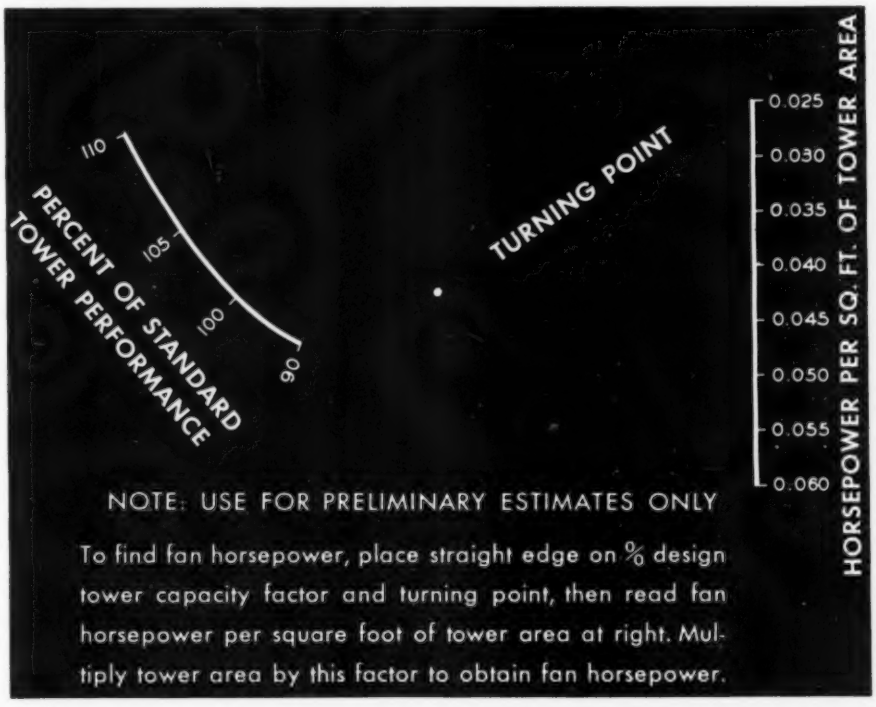

PERCENT OF STANDARD TOWER PERFORMANCE
110
105
100
90
TURNING POINT
HORSEPOWER PER SQ. FT. OF TOWER AREA
0.025
0.030
0.035
0.040
0.045
0.050
0.055
0.060
NOTE: USE FOR PRELIMINARY ESTIMATES ONLY
To find fan horsepower, place straight edge on % design tower capacity factor and turning point, then read fan horsepower per square foot of tower area at right. Multiply tower area by this factor to obtain fan horsepower.

**Fig. 3—Fan horsepower curve for induced-draft cooling towers with 24 ft. of filling**

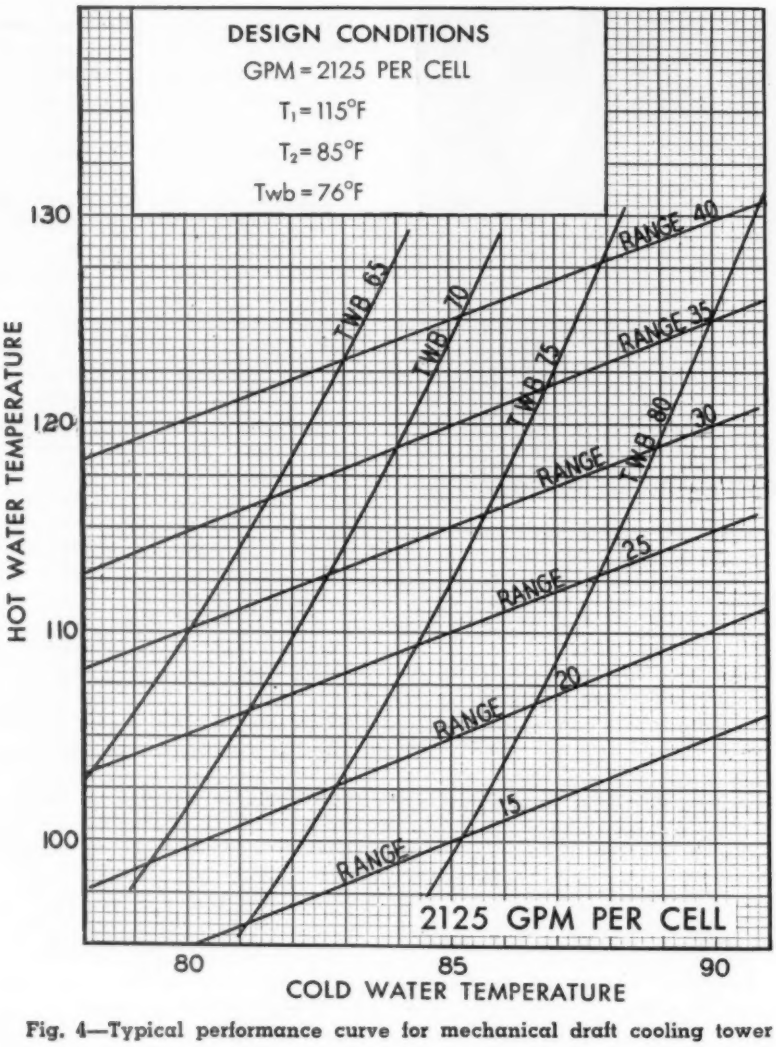



**Fig. 4—Typical performance curve for mechanical draft cooling tower**

temperature is lower. The design conditions would then be:

| | |
|---|---|
| GPM | = 2000 |
| Range | = 24° F. |
| Approach | = 8° F. |
| $T_1$ | = 92° F. |
| $T_2$ | = 68° F. |
| Wet bulb temp. | = 60° F. |

From Fig. 2, we find the water concentration required to perform the cooling is 1.75, giving a theoretical tower area of 1145 sq. ft. as compared with 1000 sq. ft. for a 70° wet bulb temperature. This shows that the lower the wet bulb temperature for the same cooling range and approach, the larger the area of the tower required and therefore the more difficult the cooling job.

The problem of estimating the performance of an existing tower at other than design conditions is often encountered by the plant operator. For example, suppose we have a tower that was designed for the following conditions:

| | |
|---|---|
| GPM | = 1000 |
| Range | = 30° F. |
| Approach | = 10° F. |
| $T_1$ | = 110° F. |
| $T_2$ | = 80° F. |
| Wet bulb. temp. | = 70° F. |

What will the cold temperature ($T_2$) be when the wet bulb temperature ($Twb$) drops to 60°, providing, of course, that the heat load and water quantity remain constant? From Fig. 2 we find that the water concentration is 2.0 gal./sq. ft. at design conditions. This water concentration does not change since the volume of water and the tower area remain constant.

With the water concentration at 2.0 and the wet bulb temperature at 60°, by adjusting the angle of the straight edge on Fig. 2 until we obtain a 30° differential between the hot water and cold water temperatures, we find the hot water temperature to be 103°, and the cold water temperature to be 73°.

Suppose now, that the above designed tower had 1500 gpm flowing through it, and the total heat load remained constant, what would the cold water temperature be when the wet bulb temperature is 65°? The design heat load was

1000 x 8.33 x 30 = 250,000 Btu./min.

The new cooling range (heat load remaining constant) when circulating 1500 gpm over the tower would be

250,000/(1500 x 8.33) = 20.0° F.

Theoretically, the design area of the tower from Fig. 2 was 500 sq. ft. (1000 gpm/(2.0 gal./sq. ft.) = 500 sq. ft.) The water concentration when circulating 1500 gpm is

1500/500 = 3.0 gal./sq. ft.

Now, referring to Fig. 2, with a water concentration of 3.0 gal./sq. ft. and 65° wet bulb temperature, adjust the straight edge until a difference of 20° exists between the hot water and cold water temperatures. This shows the hot water temperature to be 100° and the cold water temperature to be 80°.

This indicates that the possibility of a lower cold water temperature obtained by the lower wet bulb temperature was lost due to the adverse effect of the increased water quantity.

Fig. 4 shows the type of performance curve furnished by the cooling tower manufacturer. This shows the variation in performance with change in wet bulb and hot water temperature, while maintaining the water quantity constant.

The type of nozzles used in upspray cooling tower distributing systems is shown in Fig. 5. In upspray distributing systems, a pressure of 7 psi. is common practice; however, 5 psi. is adequate.

This nozzle is of the non-clogging type. It does not depend on small orifices to obtain minimum drop-size but, rather, upon centrifugal force. The water is given a spiral action by its tangential entrance into the spiral chamber. The dome-shaped approach to the discharge orifice increases this spiral action as it approaches the discharge orifice. This whirling action, which generates the necessary velocity for fine breakup, assures uniform drop-size and efficient water distribution over a maximum area. This formation of uniformly small drops assures maximum contact with air, resulting in high cooling efficiency.

(*Ed. Note:* An article further developing this subject will be published in a later issue.)

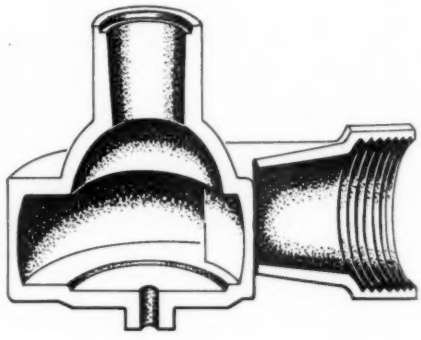


**Fig. 5—Cutaway view of an upspray nozzle showing the side entrance which starts the spiral action upward to the discharge orifice. The removable screw plate can be drilled as shown for automatic drainage, preventing winter freezing**

# TOMORROW

## ...IN PETROLEUM TECHNOLOGY

*Current technological and economic developments discussed here in the light of their future bearing on petroleum refining operations include:*

- **Peacetime demands threaten to overflow refining capacity.**
- **Increased attention being given to information services.**
- **Chemicals from petroleum reached record levels in 1946.**
- **Term "Synthine" replacing "Fischer-Tropsch".**
- **Odd correlation between the price of nylon and hose.**
- **Industrial oxygen is attracting increased attention.**
- **Petroleum company road tests its gasoline indoors.**

### *Peacetime Demands Threaten to Overflow Refining Capacity*

PETROLEUM economists have long toiled over the task of forecasting future demands and prices, and many and interesting are their correlations of these factors with business activity indices. What almost every economist failed to consider fully a few years ago, however, was the amazing resilience of American industry and the potent force of pent-up demands.

Under these influences, postwar activity has risen to new heights almost without regard, seemingly, for strikes and material shortages, and petroleum and its products —vital, as ever, to the nation as a whole —are riding the crest of record demands without apparent check in sight. In fact, even if the sometimes-forecast recession does occur late this year, economists feel that it will only slightly retard the growth in demands which now give every indication of exceeding refining capacity.

Record peacetime demands seem in order for almost every petroleum product, and prices for fuel oils are now at such peaks that refiners more than hesitate about maximizing gasoline production. Bureau of Mines' forecasts for 1947, made late last year[1] and now apparently conservative, show a total product demand of 2,010,000,000 bbls., compared with 1,927,000,000 for 1946. Some 805,000,000 bbls. of the 1947 figure represents demand for motor fuels; distillate fuel oil demand is placed at 290,000,000 bbls.; residual fuel oil demand at 490,000,000 bbls.; kerosine demand is calculated as 101,000,000 bbls.; and demand for "other products" at 324,000,000 bbls.

What is amazing about these figures is that, with the single exception of the 1944 and 1945 (wartime) demands for residual fuel oil, they constitute all-time peaks in product demands, peacetime *and* wartime. Such a situation was certainly not foreseen for 1947 even a year ago, and certainly not in 1944 and 1945, when economists were freely forecasting 1949 and 1950 as the years when demands would soar past 1941 and wartime levels.

No detailed analysis of the reasons for this situation can of course be attempted here. In regard to motor fuels, for example, the nation is witnessing the phenomenon of record demand from fewer than record number of vehicles and the pleasant prospect of future increases in demand from the peak production of cars by the automobile industry, coupled with a continued subnormal rate of scrapping. Off-highway uses—aviation gasoline, industrial naphthas, farm gasoline, etc.—also exceed 1941 consumption by a considerable figure.

Increased demand for the fuel oils—kerosine, distillate, and residual—is apparently predicated upon their popularity for home burner consumption in addition to appreciable increases in their industrial uses. A feature article could be devoted to kerosine alone; it must suffice to note that 1941 (record peacetime) demand (including exports) was only 72,690,000 bbls. and that the wartime peak reached in 1945 was only 81,753,000 bbls.

All of these demands are giving refining executives a headache—delightful on a profit basis, but severe as regards keeping normal markets satisfied and refineries operating on an efficient basis. Refining capacity has increased steadily during the war, and extensive expansions are now in progress or are being planned, but latest estimates place 1947 crude running capacity at 1,790,000,000 bbls.—considerably below demands.

Nor can material comfort be gained from imports; only in the case of crude oil do these exceed exports by any appreciable amount, and crude imports are no consolation when refinery capacity is in question.

Unless something unforeseen occurs, then, it would appear that at least regional shortages of motor fuels and fuel oils will be encountered this year, despite all-out refinery operations. Prices for crude oil and its products will probably rise in accompaniment. All in all, refiners apparently face a busy year.

### *Increased Attention Being Given Petroleum Information Services*

TRADE and technical journals such as PETROLEUM PROCESSING are always vitally interested in the uses to which the information they contain are being put, for this is a measure of their true utility and the success of their editorial endeavors. A journal may be devoted almost entirely to news reporting; in that case, its readers choose it in order to keep informed of current developments and rarely refer to it again except for statistics and confirmation of specific items. On the other hand, a journal may deal, as does PETROLEUM PROCESSING, with the technical aspects of the industry which it serves; in this case its readers not only choose it in order to keep abreast of their field but also keep it for future reference as problems arise.

No one journal can pretend to publish all the information pertaining to its purpose, however. Similarly, the vast flow of publications—journals and books—in related fields of science and technology has reached such proportions that it is almost impossible for the average individual even to keep abreast of developments in the restricted fields of his own work.

To serve as interpreters of this wealth of information, to render it effective, but "by no means to attempt to separate the scientist from contact with the primary sources of knowledge," many petroleum companies have established information service departments.

The establishment of such departments has not been a static activity, however, as evidenced by two recent publications[2], [3] and by the joint symposium on this subject scheduled to be held this month by the Divisions of Petroleum Chemistry and Chemical Education of the American Chemical Society.

As evidenced by the description[3] of its technical library, the Magnolia Petroleum Co. is typical of those petroleum companies who employ their information service groups for a multiplicity of purposes. Functions assigned to the Magnolia library apparently include: (1) provision of "a minimum list of reference

(1) Anon., NATIONAL PETROLEUM NEWS 38, No. 50, 42 (1946), "Bureau of Mines Sees 2,205,000 B/D Record Fuel Demand in 1947."

(2) Weil, B. H., *Petroleum Refiner* 26, No. 2, 152 (1947); Georgia School of Technology, State Engineering Experiment Station Circular No. 10, "Information Service and the Petroleum Industry."

(3) Fort, H. T. and Downs, L. E., *Southern Power and Industry* 65, No. 2, 46 (1947), "Designing and Operating a Plant Library."

works for use by plant officers," (2) sifting of "the mass of industrial information being issued almost daily and direction of the significant material to the supervisors within whose fields it lies," (3) performance of library research upon official request, and (4) maintenance of "clipping files on subjects of current interest to the plant." To these normal functions of an industrial library, Magnolia "has added a fifth general duty—the maintenance of a central file for the entire organization, capable of quick reference use.

Space does not permit an account of the subject matter of the other recent paper[2] on this topic, although it presents a broad and detailed discussion of the services involved and the factors pertaining to their performance. In the words of its abstract, "scientific and technologic developments of the past few decades have presented the petroleum industry with a wealth of published information for use in its highly technical, extremely diverse operations. Many petroleum companies have provided information service groups to interpret this data, as needed, and to condense, in a usable manner, the flow of current information. Such service groups, where properly staffed, also can aid in patent work, editing, advertising, and other correlated activities.

"These services, however, are often beyond the means of the smaller companies, and much needless duplication could be avoided by some organized form of intercompany cooperation. In any case, the increasing flow of published information indicates an ever greater need for technical information services."

## Chemicals from Petroleum Reach Record Levels in 1946

IN ITS annual review and forecast number, *Chemical Engineering*[4] has released some very interesting statements about the 1946 production of chemicals from petroleum. To begin with, one chart shows that while total production of synthetic organic chemicals declined nearly 1,000,000,000 lbs. in 1946 from the 1944 wartime peak of almost 15,000,000,000 lbs. (almost equalled in 1945), the production of "chemical raw materials from petroleum and natural gas" increased steadily during this period to a total of approximately 3,750,000,000 lbs. in 1946, about 28% of the production of all synthetic organic chemicals.

"While a number of new plants went into production in 1946, the year was marked by the projected expansion in diverse branches of the industry. Geographically, new plant construction is under way or being planned for most industrial sections of the country, but much of it is concentrated in the Texas gulf coast area. Significantly, this is further indication of the shifting emphasis to petroleum and natural gas as chemical raw materials.

"Accelerated by the war, the ready availability and stable supply of petroleum and natural gas has attracted much of the projected capacity in this field.

Synthetic detergents are mentioned as being "one of the fastest growing classes of compounds," with an annual capacity at the end of 1946 of some 400,000,000 lbs. compared with less than 30,000,000 lbs. in 1941. "A substantial tonnage is now based on petroleum and much of the future expansion (ultimate annual capacity has been estimated as high as 1,000,000,000 lbs.) will be petroleum derived. According to some predictions, up to 50% of total soap requirements may be met by products containing synthetic detergents. Bulk of this material will be furnished as intermediates to the soap industry."

Other petroleum chemicals soon to be produced in increased quantities include ethyl alcohol and ethylene glycol. In 1946, "producers of synthetic alcohol turned out about 65,000,000 gals., but virtually none of this came on the open market.

Few other specific figures are presented, but the trend indicated is certainly significant. Petroleum and natural gas will more and more be used as raw materials for chemical synthesis.

## Term "Synthine" Replacing "Fischer-Tropsch" in America

IT HAS now been two years since comment was made in this series[5] that "the use of the term 'Synthine' is becoming well associated with the many variations of the hydrogenation of carbon monoxide to hydrocarbons." Since that time, it has been used to an increasing extent in place of the awkward "Fischer-Tropsch," the confusing "gas synthesis," the ambiguous "indirect hydrogenation of coal," and the technically correct but lengthy "hydrogenation of carbon monoxide to hydrocarbons and oxygenated derivatives."

Only time will tell if this Anglicized version of the German term "Synthin" (*Synth*etisches Benz*in* or, translated, *syn*thetic gasol*ine*) will completely replace the more familiar "Fischer-Tropsch" in technical terminology, but it has already been used to a considerable extent and, it is reported, will be employed in the first book to be devoted to the process.

It is interesting to note that a recent article[6] comments that "the 'Synthine' process is a name which is apparently being accepted in the United States, in lieu of Fischer-Tropsch, to make products which are intermediate betwee the Kogasin and Synthol syntheses; namely mixtures of hydrocarbons and oxygenated products." This is probably not quite correct, however, since in most cases the term "Synthine" has been used to refer to *all* syntheses which involved the reaction of hydrogen and carbon monoxide to yield hydrocarbons, oxygenated hydrocarbons, and mixtures of both.

Furthermore, the other terms, "Kogasin" and "Synthol," are used in this definition[6] to refer to processes (or products therefrom) which involve the predominant production of liquid hydrocarbons and oxygenated hydrocarbons, respectively. Again, this usage is not rigorous, since the term "Synthol" is apparently being used in this country by at least one engineering company (Kellogg) to describe a process in which hydrocarbons presumably predominate in the products.

In German terminology, "Kogasin" (from the German words for coal-gas-gasoline) is used synonymously with "Fischer-Tropsch" to relate to the production of hydrocarbons, but its generic meaning (reference to coal as raw material) negates its American interpretation and use, at least as long as natural gas is used as raw material. The original German "Synthol" process did relate to the predominant production of oxygenated hydrocarbons, but, as mentioned, the American usage of the term apparently differs in meaning.

Hydrocarbon Research, Inc., has applied the tradename "Hydrocol" to its process, which produces largely hydrocarbon products (but some oxygenated compounds). Other tradenames may well appear, since competition between companies will prevent acceptance of each other's names. In the discussion of overall technical and economic problems, however, it will always be necessary to employ a term or terms which describe all processes in a general way, and it is for this use that the term "Synthine" is being increasingly employed in American terminology.

Generic meanings and technical accuracy are of little concern to the nontechnical public, but such difficultly-spelled words as "Fischer-Tropsch" can hardly be expected to have much appeal for use in connection with a process which will be increasingly in the public eye. No one will ever deny the technical contributions of the men themselves, but it seems unnecessarily sentimental to burden future terminology with their names.

## Odd Correlation Between Price of Nylon and Hose

NOW that nylon has become a "plastic from petroleum" by virtue of the near-future production of its intermediates from petroleum-derived cyclohexane at du Pont's plant at Orange, Texas, it is quite proper for one to discuss the delicate subject of ladies stockings in the midst of a technical journal.

All of which leads to an interesting correlation between material costs and retail prices, for, when du Pont cut its prices

(4) Anon., *Chemical Engineering* 54, No. 2, 112 (1947), "Synthetic Organic Chemicals."

(5) Anon., NATIONAL PETROLEUM NEWS, *Technical Section* 37, No. 18, R-366 (1945), "Keeping Up With the News—Synthine Defined."

(6) Downs, C. R. and Rushton, J. H., *Chemical Engineering Progress* 1, No. 1, 12 (1947), "Tonnage Oxygen."

on nylon yarn about 6% early last month, "the hosiery trade was quick to point out that . . . the cost of the yarn represents a very small part of manufacturers' production costs—only a fraction of a cent on a pair of hose. Other much more important cost factors show no sign of tapering off. They include labor, finishing, spoilage, and amortization of machinery(7)."

It is beside the point that nylon production is being increased considerably, also that the above quotation probably meant that it was the 6% reduction that represented only a fraction of a cent, not the total cost of the nylon per pair of stockings. What is important is the reminder that reduced production prices of chemicals are not always passed on to the consumer of the ultimate finished product because they often represent only a small part of the retail price. On the other hand —and refiners are intimately familiar with the merits of processes which save a few mills per gallon on millions of gallons—such reductions are highly important to quantity consumers and are "good business" in an industry in which there are competitors (silk and rayon).

Chemical economics are not wholly familiar to petroleum processors, although this situation is rapidly changing. While the retail price of gasoline, for example, is a several times multiple of refinery costs, because of taxes, transportation costs, and marketing costs, the margins in this mass production industry are small when compared with those industries which produce far lesser quantities—but at higher unit profits. Time does not permit consideration of the countless other factors which pertain; all that need be noted here is that there is very little profit for the petroleum industry in a single pair of milady's hose.

## Industrial Oxygen Is Attracting Increased Attention

UNDER the titles of "Oxygen—Past, Present, and Prospects"(8) and "Oxygen Steps Into Star Role,"(9) two recent articles have served to augment February's article(10) on this subject and to call attention to some of the salient facts about industrial oxygen, a chemical rapidly assuming major importance "in the oil and steel and perhaps the gas industry."

Unlike the customary 99.5% oxygen of commerce, "tonnage oxygen" will probably range from 90-95% in purity requirements. Absolute purity is not required in the Synthine process, for example—and it is here that this substance may find considerable use, first for the preparation of synthesis gas by partial oxidation of natural gas (methane) and ultimately (perhaps) for the synthesis of this gas from coal and lignite, possibly by continuous processes.

In the iron and steel industry, the availability of cheap oxygen might make it possible to increase furnace capacities by 25% through use of oxygen instead of air to reduce the metal and oxidize purities. Using oxygen, it might even be possible to produce steel directly in the blast furnaces. The manufactured gas industry might also benefit from gas-making processes similar to those described above for Synthine synthesis gas.

Wartime research in this country and the availability of German technical information on oxygen separation processes are accountable for the new prospects for low-cost oxygen, formerly sold largely in cylinders or tank cars and seldom produced directly by the consumer. "Newly developed heat exchangers now cool air to the liquefaction point at much lower pressures. Another improvement simplifies the removal of unwanted water and carbon dioxide from the air. Turbocompressors replace conventional piston-and-cylinder compressors in some models."(9)

High-purity oxygen is currently available for $3 to $20 per 1000 cubic feet, depending upon the quantity—and largely occasioned by the high purity requirements, transportation costs, and technical services provided. No absolute figures are yet available for the new processes, although "tonnage oxygen users and producers are talking in terms of 10 cents or less per 1000 cubic feet."(9) "One engineering firm (presumably Hydrocarbon Research, Inc.) estimates 4.8 cents for 1000 cubic feet of 95% oxygen in a plant of 48,000,000 cubic feet per day capacity,(8) although this cost is undoubtedly predicated on the use of heat from the exothermic Synthine synthesis process to supply steam to power the compressors.

In addition to the oxygen industry's "Big Three"—Air Reduction Co., Linde Air Products Co., and Natural Cylinder Gas Co.—several companies familiar to the petroleum industry will probably be major competitors in the industrial oxygen field, "selling engineering service or oxygen generating units rather than oxygen itself."(9) This group includes the M. W. Kellogg Co.; the Elliot Co.; Arthur D. Little, Inc.; E. B. Badger & Sons; Independent Engineering Co.; Air Products, Inc.; etc.

The petroleum industry will watch with interest further developments in the field of low-cost oxygen production. Use in the Synthine process would be reason enough for this attention, but potential applications in the manufactured gas industry (based on coal) are probably of equal significance, helping to assure, as they do, the semi-inexhaustibility of the nation's supply of gaseous fuels, natural and otherwise.

## Petroleum Company Road Tests Its Gasoline Indoors

IT has long been known in the petroleum and automotive industries that, no matter how well developed the engine and technique, no laboratory test on a laboratory engine gives quite as satisfactory a gauge of gasoline quality as do tests in an automobile under actual driving conditions. For this reason, many petroleum companies operate fleets of cars thoroughly equipped with instruments designed to measure octane number (by comparison with standard fuels), power, etc.

"Excellent results are achieved under ideal conditions, but such are not always found on modern highways"(11) because of heavy traffic; variations in weather which invalidate comparisons; traffic noise; etc.

To overcome these obstacles, yet still obtain road test data on its gasoline, the Gulf Research & Development Co. has recently constructed a "revolutionary road-test dynamometer which creates a highway within the laboratory." A regularly equipped test car is driven onto the test floor of this mechanism; "its front wheels are fastened to prevent any forward motion, while the rear wheels rest on and turn the drums which gear into the massive mechanism below stairs. . . .

"Mileage and other pertinent test data are recorded on a huge instrument board outside the car. The rear wheels rotate heavy drums which gear into flywheels, electrically manipulated to simulate various vehicle and passenger loads. A combination electrical motor and absorbing unit creates artificial uphill and downhill grades by speeding or retarding the drums, while a fan delivers air against the car at a velocity proportionate to its 'speed,' and an air conditioner supplies artificial (outside) temperatures. A siren warns of mechanical failures, and an outside scale indicates torque."

Dynamometer running hours are said to be nearly 100% productive; full attention can be devoted to the test aspects of the job, dismissing all traffic responsibilities; the quiet of the laboratory renders motor "ping" gauging of higher precision; and the mechanism does not have to be "laid up" when the weather is bad outdoors.

A more technical description of this dynamometer will undoubtedly reveal more details as to its cost, results of its operations, and a more detailed appraisal of its future.

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(7) Anon., *Business Week*, No. 913, 57 (1947), "Cheaper Nylons? Not Yet."

(8) Anon., *Chemical Engineering* 54, No. 1, 123 (1947).

(9) Anon., *Business Week*, No. 909, 72 (1947).

(10) Anon., PETROLEUM PROCESSING 2, No. 2, 113 (1947), "Fischer-Tropsch Process (U. S. Model) Is Means of Supplying Low-Cost Oxygen."

(11) Anon., *The Orange Disc*, 7, No. 10, 12 (1946), "Touring 'The Great Indoors'."

# *GAS TO BURN*... but how?

An open flare is one way to burn gas... but an expensive waste of natural resources, too. Yet billions of cubic feet of gas..."sour" gas which has too much hydrogen sulphide to be commercially usable... are burned this way in this country every year.

The FLUOR Glycol-Amine Gas Treating Process converts "sour" gas into a useful source of fuel by removing the excess hydrogen sulphide to within pre-determined limits. Gas thus treated is *guaranteed* to meet the Bureau of Standards Lead Acetate Test, in accordance with Government Regulations.

The cost of treating "sour" gas by the FLUOR Glycol-Amine Process is low enough to leave a comfortable margin of profit at lowest rates for bulk distribution.

Owners and operators of gas producing properties will find it to their advantage to submit gas-treating problems of all kinds to FLUOR.

**FLUOR** GLYCOL-AMINE GAS TREATING PROCESS
PATENTED

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ENGINEERS • MANUFACTURERS • CONSTRUCTORS

# PLANT PRACTICES

## More Floor Space and Simplified Piping Results from Mounting Pumps on Posts

MORE floor space and simplification of piping resulted from mounting on posts the pumps in the filter department of the lubricating oil plant at Continental Oil Co.'s Ponca City refinery.

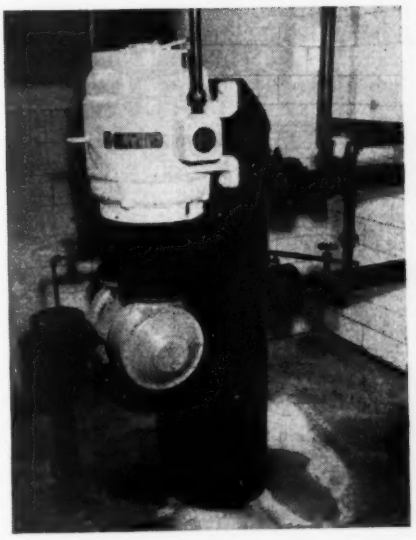
The arrangement is shown in the accompanying photographs. These units, ranging in size up to 350 gpm for gear pumps and 500 gpm for centrifugal pumps, are mounted on pedestals built of scrap pipe.

The posts are made from convenient lengths of 8 and 10 in. pipe, carrying a welded-on pedestal made from sheet steel, and set in a flange bolted to stud bolt projecting from the concrete floor.

Connecting piping comes down from headers anchored off the floor, which permits elimination of a good many ells, tees, and other pipe fittings otherwise required in the case of conventional floor mountings. Power lines are carried in overhead conduits with leaders running down from the ceiling to each unit.

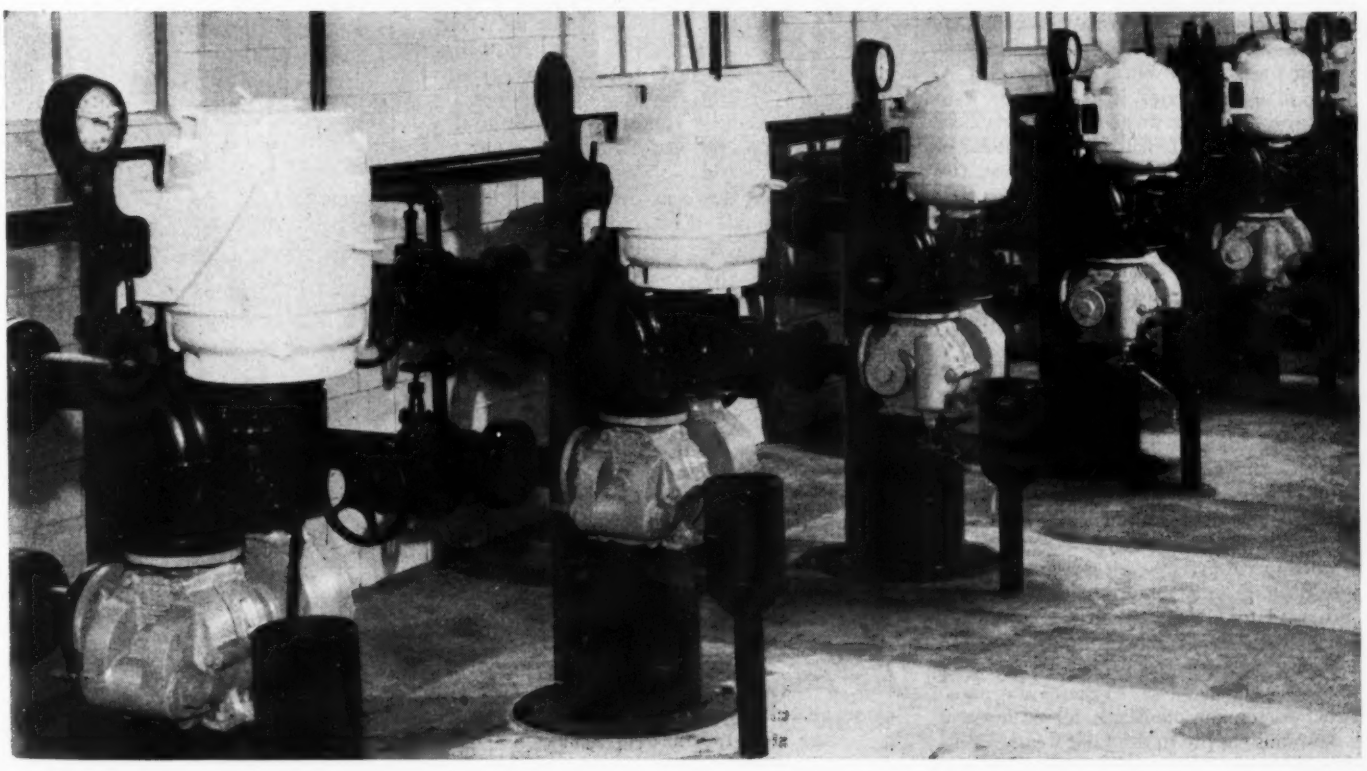
The layout makes cleaning an easy task, There is also less chance of an employe coming in contact with the pump or drive through accident, and reduced possibility of damage to the pump from a heavy object being dropped on it or liquid spilling over it.

There are probably many possible adaptations of this unique pump mounting method that could be used in the modern petroleum processing plant. Experience of operating engineers has substantiated the value of good layout planning and clean surroundings in increasing efficiency.



**Above. Close-up view of scrap pipe pump mounting showing simple but rugged construction**

**Good housekeeping is a simple and easy job in the pump room of Continental Oil's lube oil filter department**



# Thermocouple Actuates Waste Gas Torch Ignitor When Pilot Flame Fails

By ALFRED KRIEG, Supervisor, Instrument Department
Socony-Vacuum Oil Co., Inc., Paulsboro (N.J.) Refinery

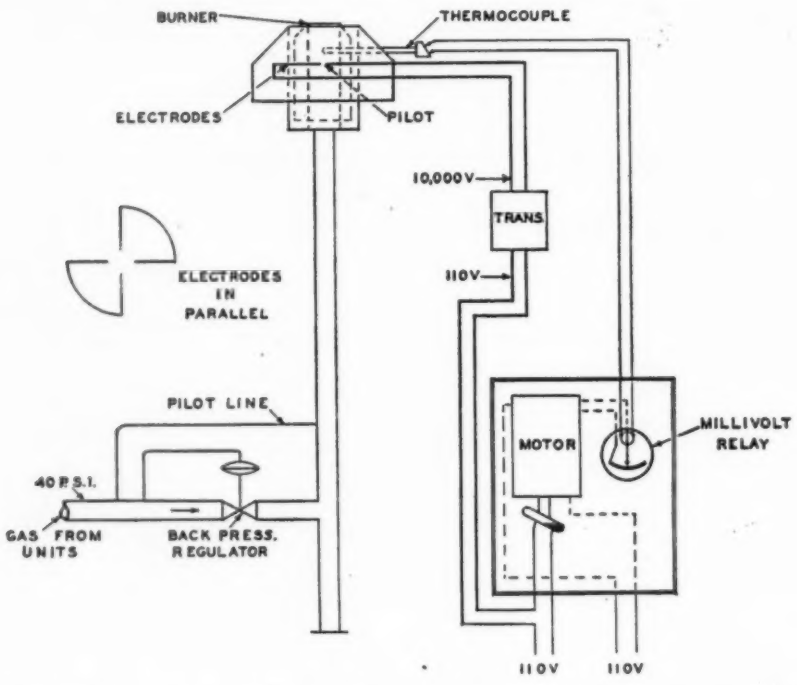



**Fig. 1—Automatic waste gas torch ignitor. When pilot flame goes out, thermocouple cools, actuating millivolt relay, and starting motor**

FAILURE of the pilot flame in a refinery waste gas torch can be avoided by means of an electrically-operated safety device developed by Socony-Vacuum engineers. It consists of a thermocouple arrangement automatically providing spark at the burner.

In many refineries it is customary to burn the excess or waste gas by means of a torch equipped with a gas pilot. In Socony-Vacuum's Paulsboro refinery, the gas distribution system is designed so that more than 98% of the gas is utilized in the various furnaces and boilers throughout the refinery. The remaining 2% excess or waste is spilled over to the torch. This spillover is controlled by means of a back pressure regulator, discharging gas in excess of 40 psig into the torch line.

Line pressure between 35 and 40 psig is maintained in the gas manufacturing area with all gas being sent to various units in the yard when the pressure exceeds 35 psig. In the event the manufactured gas exceeds the amount which can be utilized in the yard, an increase in pressure above 40 psig results, with the gas spilling into the torch line through the regulator.

It is standard practice to maintain a pilot flame at the torch at all times. A small pilot line, which bypasses the regulator, passes sufficient gas to maintain a continuous supply to the pilot flame. However, on occasions, the pilot flame may be extinguished because of weather conditions, etc. The method employed to ignite the flame in case of failure is shown in Fig. 1.

The thermocouple with a protective tube or well is located in the gas burner at a point where the heat from the pilot flame will be projected on the couple. The thermocouple is connected directly to a millivolt relay which is in turn connected to a small motor of the telechron type. The motor, by means of a cam arrangement and mercury switch, energizes the primary circuit of the transformer. This in turn delivers 10,000 volts to the electrodes which creates the spark to reignite the pilot flame.

In the event the pilot flame fails the thermocouple cools off, causing a reduction in emf produced. When the emf is reduced to a certain point, the circuit in the millivolt relay is closed causing the motor cam arrangement to close the mercury switch and energize the primary element of the transformer. This arrangement is designed to make contacts for the 10,000-volt circuit at 15-second intervals so long as the millivolt relay circuit is closed. With this circuit open, the wiring is arranged to return the mercury switch to the off position.

Since the electrodes are subjected to much corrosive action by the gas they must be made of metal such as stainless steel which will resist this action. There are four electrodes in the burner with two sets of each connected in parallel thereby minimizing the amount of wear and maintenance.

# Rigging Technique for Painters' Stages Will Eliminate Swaying and Prevent Falls

A STABILIZER for a painter's stage which will prevent swaying, even in high winds, and prevent a dangerous fall in the event the stageline should break was the subject of a safety suggestion by a painter at the Baytown refinery of Humble Oil & Refining Co.

As shown in Fig. 2, the method employs the use of an additional sling line around the base of a stack being painted. A safety line is rigged through a hole in the painter's stage and attached by hooks to each of the sling lines around the stack. A ratchet on this safety line, attached close to the bottom sling line, adjusts tension on the safety line, thus preventing the stage from swinging to and fro either from movements of the workmen or from the wind.

The ground crew need pay no attention to the safety line except when moving the stage, when it must be temporarily loosened to permit raising or lowering.

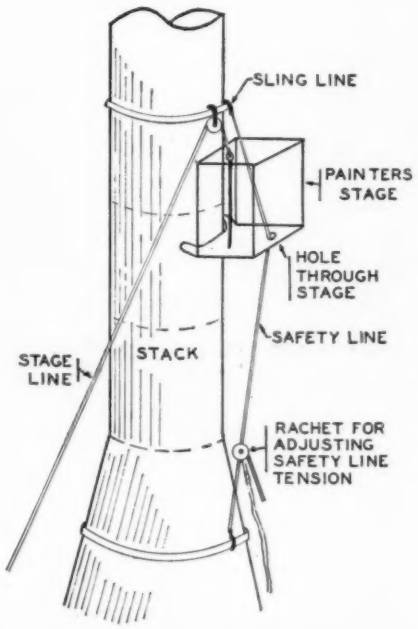



**Fig. 2—Safety line prevents swaying of stage, also stops fall in case regular stageline should break**

# Pressure-Operated Switch Simplifies Remote Control of Loading Rack Pumps

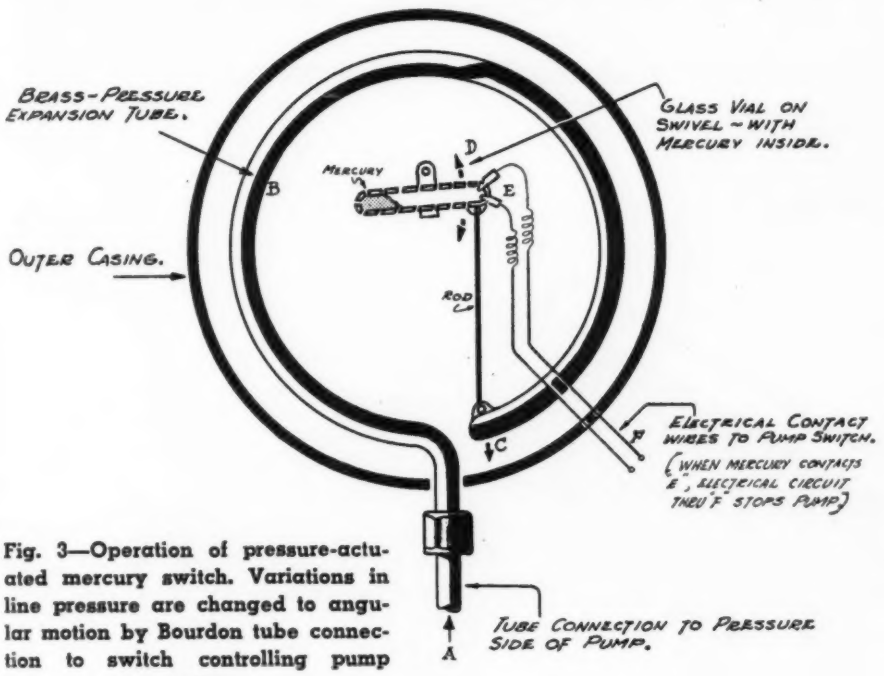
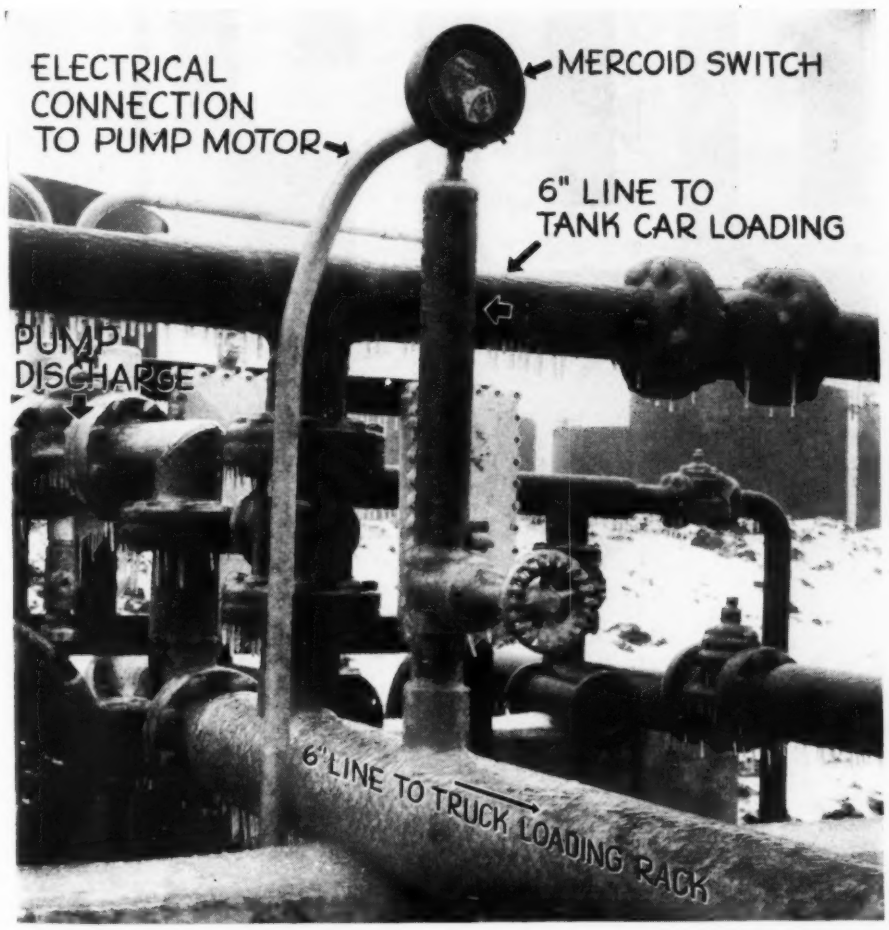



**Fig. 3—Operation of pressure-actuated mercury switch. Variations in line pressure are changed to angular motion by Bourdon tube connection to switch controlling pump motors**


ELECTRICAL CONNECTION TO PUMP MOTOR
MERCOID SWITCH
6" LINE TO TANK CAR LOADING
PUMP DISCHARGE
6" LINE TO TRUCK LOADING RACK

**Close-up of the switch installed on a loading rack pump manifold at Sinclair Refining Co.'s Toledo pipeline terminal**

A PRESSURE-OPERATED, mercoid switch placed on the discharge side of a loading rack pump and connected to the pump motor has saved one oil company the expense of installing extensive electrical equipment, conduits and the like, to the loading rack.

Developed by Sinclair Refining Co. Inc., for use at the Toledo pipeline terminal, the device will eventually be used in all Sinclair loading operations, both tank car and tank truck. It is said to be equally adaptable to pumping systems in refineries as well.

A small diameter line is tapped into the 6-in. outlet pipe from the centrifugal pump, and a commercially available mercoid switch placed at the end of the line, as shown at *A* in Fig. 3.

As long as the loading spout valve is closed, pressure in this line expands the brass tube *B*, forcing point *C* outward in the direction of the small arrow, and tilting mercury tube *D* in a clockwise direction. This motion brings the mercury to the right end of the tube and closes contact *E*, so that electrical circuit through *F* stops the pump.

When the loading valve is opened, the pressure inside tube *B* is relieved, point *C* returns to its normal position, and the electrical circuit through *F* is broken, starting the pump.

Development of the device started when, because of a rearrangement in piping and manifolding, Sinclair was faced with cutting through 8 inches of concrete thickness of a large paved area to install conduit. Chief advantages include: (1) simplicity and positiveness of operation, (2) minimum amount of moving parts, and (3) elimination of the need for a maze of electric conduit, wire and control buttons used in the case of remote control electrical apparatus.

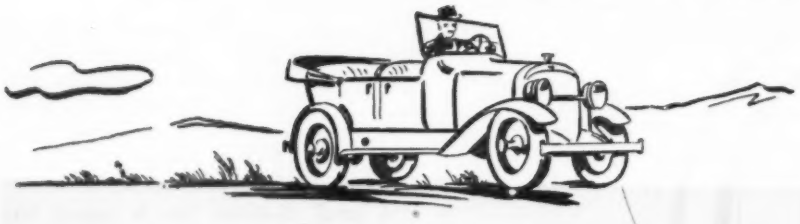
### *IDEAS—Wanted!*

Plant operators, foremen, superintendents!—send in your own original contributions on "how we do it around our refinery." Possible subjects could include operating shortcuts, time and money-saving gadgets, repair ideas, accident and fire prevention schemes. Include photographs, drawings, or graphs, if available.

Material submitted for publication exclusively in PETROLEUM PROCESSING is paid for at the usual space rates. The idea is the thing—we'll dress up the drawings and the written information. Send your contributions to:

Plant Practices Editor
PETROLEUM PROCESSING
1213 West Third St.
Cleveland 13, Ohio

# More than 30 years of



UOP

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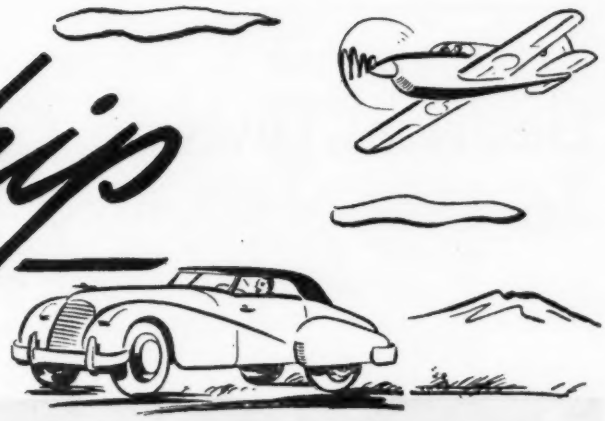
# Leadership



More than thirty years ago, in a small laboratory at Independence, Kansas, a group of UOP technologists were working on what was to revolutionize the refining of crude oils. The result of their labors was the UOP Thermal Cracking (Dubbs) Process... a process that added a new chapter to the history of petroleum refining.

From that day forward, UOP has maintained the leadership which they established with that momentous discovery. New processes... new inventions... new developments... have come out of the UOP laboratories during these fruitful years, making possible the doubling of gasoline yield per barrel of crude and the continuing improvement of gasoline to its present day quality. And hundreds of UOP units... comprising eleven different processes or combinations of processes ... have been installed in the United States and 27 foreign countries.

Today, as always, UOP is dedicated to the further development of refining processes in an unceasing effort to provide even greater efficiency in gasoline production... higher product quality ... and lower operating costs. And, as in the past, these new developments, as they are proved commercially practical, will be made available to refiners all over the world.

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UNIVERSAL SERVICE PROTECTS YOUR REFINERY

# Electrical Division Contributes To Utopia's Safety Record

By FRANK J. SLUZE, Safety Director
Ashland Oil & Refining Co.

An inspection of the activities of the electrical department in the mythical refinery of Utopia shows why complete safety is a goal possible for any petroleum processing plant.

CONTINUING with our inspection of Utopia, the refinery of perfection, we find ourselves in the Electrical Department. On our first stop, we note that the electrical shop is of fire-resistant construction, and is situated in the administration area well away from the operating area.

Over there a fellow is washing an electric motor about to be overhauled. We learn the liquid used is not gasoline but a high flash solvent—that's fine! The foreman informed us that gasoline is forbidden as a cleaning solvent due to its being a fire hazard as well as a dermatitis risk. We can't help noticing also that the solvent is kept in a safety can equipped with a closing spring and fusible link which will close the lid automatically in the event of fire.

### Monorail for Heavy Objects

Overhead is a monorail and traveling chain-hoist for handling heavy material —a good precaution against sprains, strains, and other injuries.

The storage battery charging station is located in a small room off the main shop. It is well ventilated to carry off flammable gas generated during the charging.

Now we enter the room used for storing "hot line" material. The room is dry and well ventilated to keep moisture to a minimum. Here we find rubber gloves, insulating sticks, rubber tubing, fuse pullers, rubber overshoes, and lineman's belts. Inquiring, we learn that the rubber gloves and lineman's belts have all been tested to see that they are in good operating condition.

Utopians always place a warning sign before working on electric equipment

Coming out of this small room into the main shop again, we notice a supply of padlocks and "Danger, Men Working on Line" signs used to prevent someone's throwing in the power while another man is working on a line or equipment.

Over on the wall is a framed list of instructions on how to administer artificial respiration. We learn that all electricians have been taught the different methods of performing artificial respiration as a part of their first aid course.

Having finished our inspection of the shop, we are now on our way to the operating area. Notice that all wooden service poles have been replaced with metal ones—a good safety precaution. Wooden poles will furnish ready fuel and are more likely to fall than metal ones in case fire reaches them, and in falling, bring down the live power lines. Our inspection of explosion-proof lights shows them in good operating condition —outer globes in place—gaskets in place, conduits sealed, and lines well insulated.

### Motors Are Grounded

Let's go over and inspect that motor. Notice that it is properly grounded; also the plate on it shows that it is approved for Class I, Group D atmospheres and equipped with Class I, Group D starting switch. The foreman tells us an explosion-proof motor is *only* explosion-proof when kept in the *original factory condition*. Therefore, all electricians have been instructed to reassemble motors to exactly duplicate their original condition.

There comes a workman carrying a portable electric drill—wonder if it is equipped with a ground wire. Examining it, we find that an extra wire has been attached to the housing of the drill, and the other end has a clip for attaching to a ground—no fear of an accidental shock while using this drill.

Let's examine the extension light cords —notice that the lights are explosion-proof and the cable is dry and free of bare spots, kinks, and taped joints. The plug is of explosion-proof design as is the wall receptacle. Note that the cable carries a third, or return, wire within the main covering.

Journeying through the plant, we note that trees in the vicinity of the high tension lines have been trimmed to keep them away from the line a distance of at least ten feet.

Over there we see a transformer station. Closer observation reveals that the station is fenced in, and the gate is locked. The key to this lock is in charge of the electrical force. On all four sides we see a standard "Danger, High Voltage" sign. We also notice carbon dioxide fire extinguishers hanging on brackets at convenient locations.

Inspecting the loading rack railroad spur, we find that the rack, piping and loading spouts are grounded at required intervals. At the spur entrance the rail joints have been provided with insulating strips. This bonding and insulating eliminates any possibility of static electricity or stray current.

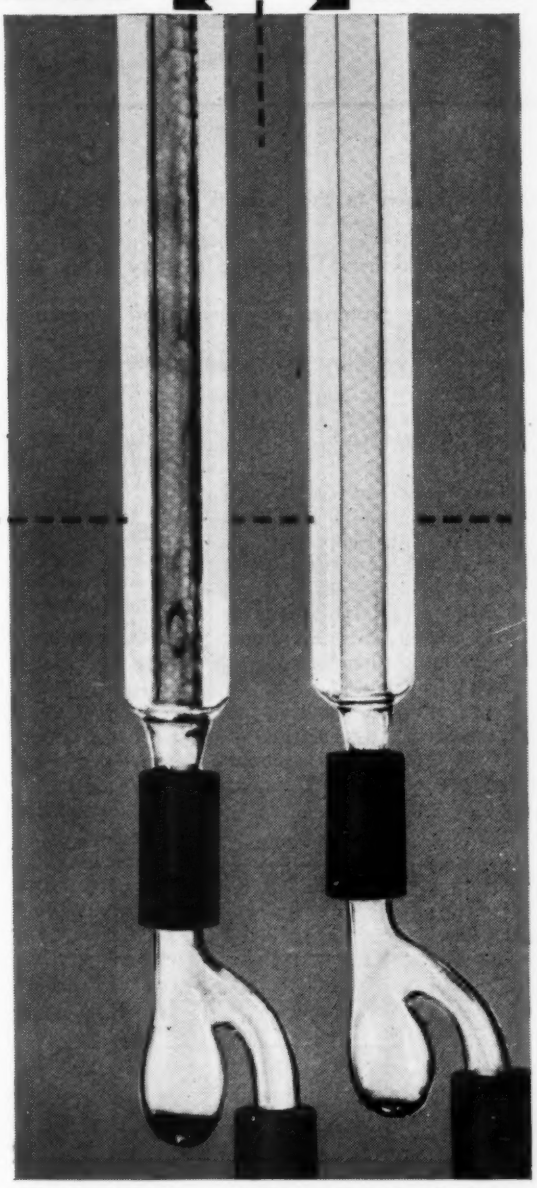
### Insulating Oil Is Tested

Arriving at a switch panel, we learn from the electrician that the insulating oil used to immerse the electric arc has been tested and found to have a dielectric strength of greater voltage than that which will possibly prevail at any time. Examining service pole guys on high tension lines, we find that an insulator has been provided on each guy sufficiently high to provide ample clearance above ground and in no case less than 8 feet.

Discussing upkeep of explosion-proof motors with the Chief Electrician, we learn that all motors are taken into the shop at least once a year and reconditioned to assure them being in safe operating condition.

In Utopia ALL electricians know the proper method of artificial respiration

# These 2 tubes tell the story...




**(Vertical glass manifolds, operated at 150 deg. F. mixture temperature, show effect of PARADYNE FUEL IMPROVER on deposits.)**

Two gallons of motor fuel were passed through each of these two glass manifolds connected to a test engine. One fuel was straight gasoline, the other was treated with Paradyne Fuel Improver.

When your gasoline performs like that in the right hand tube . . . Paradyne-improved . . . you're well on your way to pleasing customers and building sales with a gasoline that helps keep harmful gum deposits to a very minimum!

Write for Technical Bulletin No. 101 for complete information on Paradyne Fuel Improver.

# PARAMINS* make good fuels and motor oils better!

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PARAMINS INCLUDE:
**PARATONE** —*for improved viscosity index.*
**PARAFLOW** —*for lower stable pour.*
**PARATAC** —*for tacky oils and greases.*
**PARAPOID** —*for E.P. gear oils.*
**PARANOX** —*for inhibiting corrosion and oxidation.*
**PARASHEEN**—*for better appearance.*
**PARADYNE** —*for improved gasoline.*

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# Patent Trends in Petroleum Refining

By Peter J. Gaylor

*Patent Attorney and Editor "The Technical Survey"*

**Developments disclosed in the patents reviewed below include:**

**Sulfuric acid alkylation improved by oxy acids of phosphorus.**

**Tin tetrachloride promotes conversion of hydrocarbons to aromatics.**

**Replace expensive alloy tube sheets with refractory supports.**

## *Sulfuric Acid Alkylation*

IN SULFURIC acid alkylation, an acid concentration of 90-100% is generally employed, with temperature at 14°-86° F. Practical experience has shown that when the acid concentration is below 95% $H_2SO_4$ (i.e. the acid contains over 5% water), the alkylation effected is less desirable than when acid of 95-100% $H_2SO_4$ is used. But, in this higher concentration range, the acid oxidizes and polymerizes a portion of the reactants to terpene-like resinous materials which accumulate in the acid and ultimately render it inactive as a catalyst for further alkylation.

When 100% sulfuric acid is diluted with as much as 10% water, its ability to catalyze alkylation is substantially impaired, presumably because of formation by the acid molecules of stable hydrates which are incapable of activating the alkylation reactants.

In its U. S. 2,413,777, California Research Corp. discloses that when concentrated sulfuric acid is compounded with and diluted by the organic compounds of the oxy acids of phosphorous, the tendency of the acid to produce undesirable oxidation and polymerization of the reacting hydrocarbons may be reduced materially, while its ability to promote the alkylation reaction remains substantially unimpaired.

These compounds resemble sulfuric acid and have as their characteristic or central atom, the acid-forming element phosphorous. A substantial increase in the active life of the catalyst and an extension of the temperature range in which it is active without serious attack on the hydrocarbon constituents of the reaction are additional advantages.

As can be seen from Fig. 1, the octane number of the product increases in concentration of butyl pyrophosphoric acid in sulfuric acid up to a maximum at about 10-15 wt. % of butyl pyrophosphoric acid, beyond which octane number begins to drop and bromine number rises sharply.

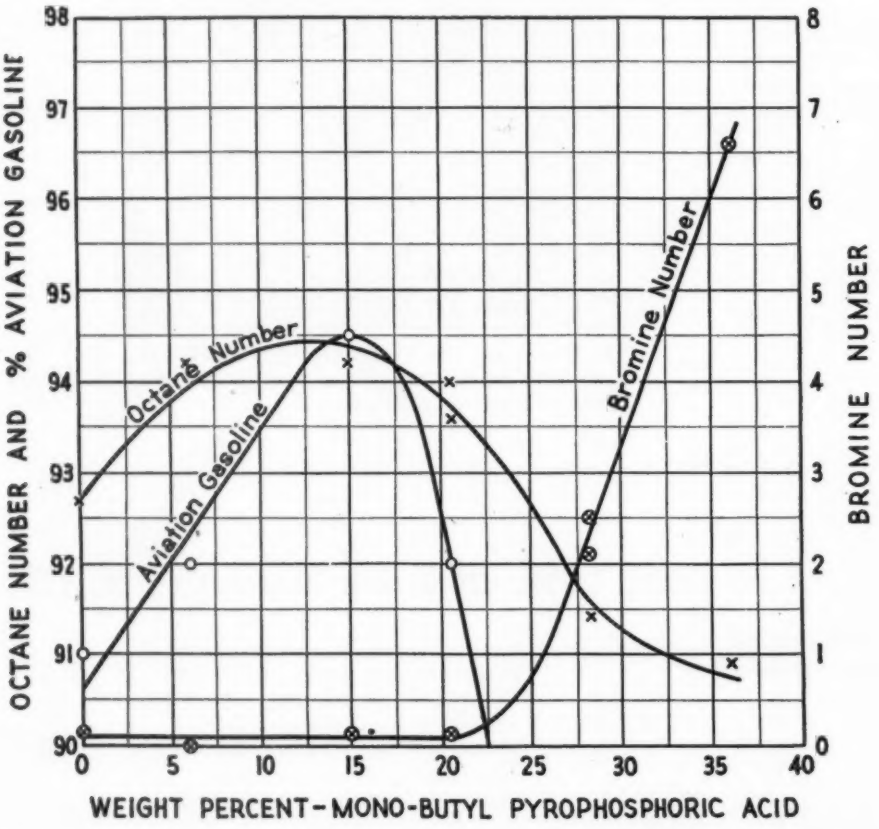



**Fig. 1—Effect on octane and bromine number of aviation gasoline by addition of mono-butyl pyrophosphoric acid to sulfuric acid alkylation catalyst (U. S. 2,413,777)**

## *Aromatics from Methane*

THE CONVERSION of methane to useful products has been a perennial problem, with nothing yet, outside of the Fischer Synthesis, to offer hope to the gas owner. Many a project of a chemical nature began with methane as a seriously selected raw material, and ended up with propane and butane, which still have only fuel value and are much more reactive.

Socony-Vacuum Oil Co. has obtained U. S. Patent 2,396,697 describing the conversion of normally gaseous hydrocarbons into aromatics by means of a promoted high temperature reaction. The best promoter, tin tetrachloride, enters the reaction, as follws:

$$6CH_4 + 9SnCl_4 \rightarrow C_6H_6 + 9SnCl_2 + 18HCl$$

The tin compound is reduced during the aromatization which takes place at 600-1200° C.

It is important to note that, for the first time, production of substantial amounts of benzene have been obtained from methane at temperatures below 1000° C.

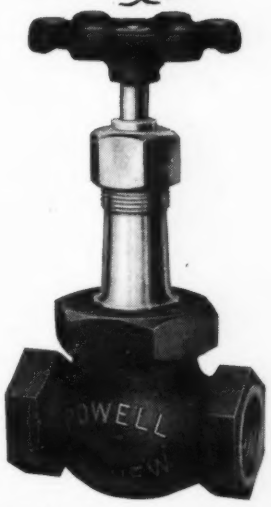
The amount of induced decomposition, relative to the amount of the direct reaction of methane with the metal halide is greater the higher the temperature and the higher the ratio of methane to metal halide used. When a methane-mercuric chloride mixture containing 15 mol-% of mercuric chloride was pyrolyzed, the outer periphery of the tube being 925°

# For assured flow control, the valve must suit the service

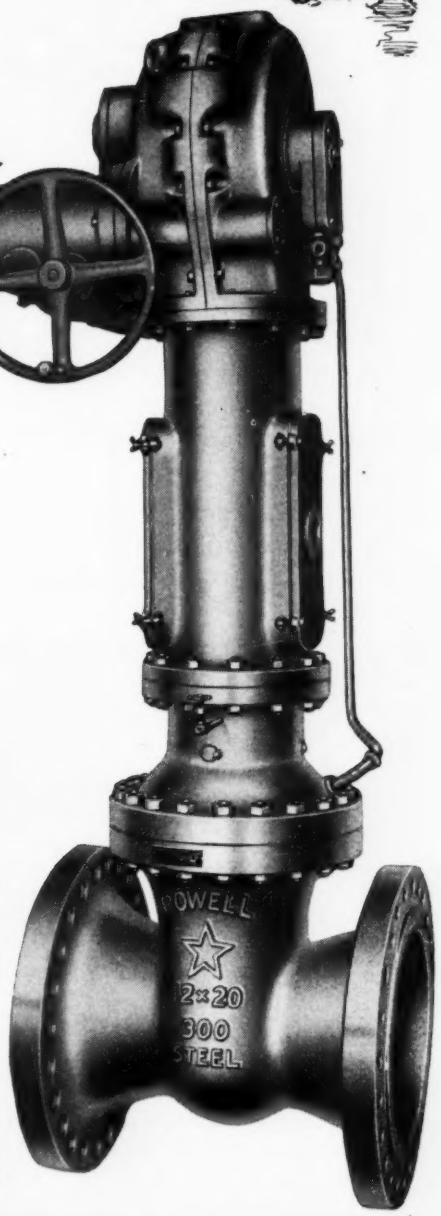
You don't have to be an Isaac Walton to know what's wrong with these fishing pictures. Silly misapplications of equipment, aren't they? But no sillier than using *valves* in services for which they were not specifically designed.

Through more than a hundred years of making valves—and valves only—Powell Engineers have been designing the *right* valves to suit the specific requirements of every existing industrial flow control service. Today, the Powell Line includes Bronze, Iron and Steel Valves of every necessary type, design, size and pressure. And, for corrosion resistance, Powell makes a notably complete line in the widest range of pure metals and special alloys ever used in making valves.

That's why, *for assured performance,* it pays to consult Powell.




Small size 150-pound Iron Body Bronze Mounted "Irenew" Globe Valve for steam, oil, water or gas. For assured, long-life performance, it has regrindable, renewable wear - resisting "Powellium" nickel-bronze seat and disc.




Class 300-pound Cast Alloy Steel Gate Valve built to meet special requirements and to handle high temperatures. Has 12" port size venturied to 20" size end flanges to accommodate insulated pipe. A top-mounted, fully enclosed, explosion-proof electric motor operator provides quick, positive opening and closing by remote control.

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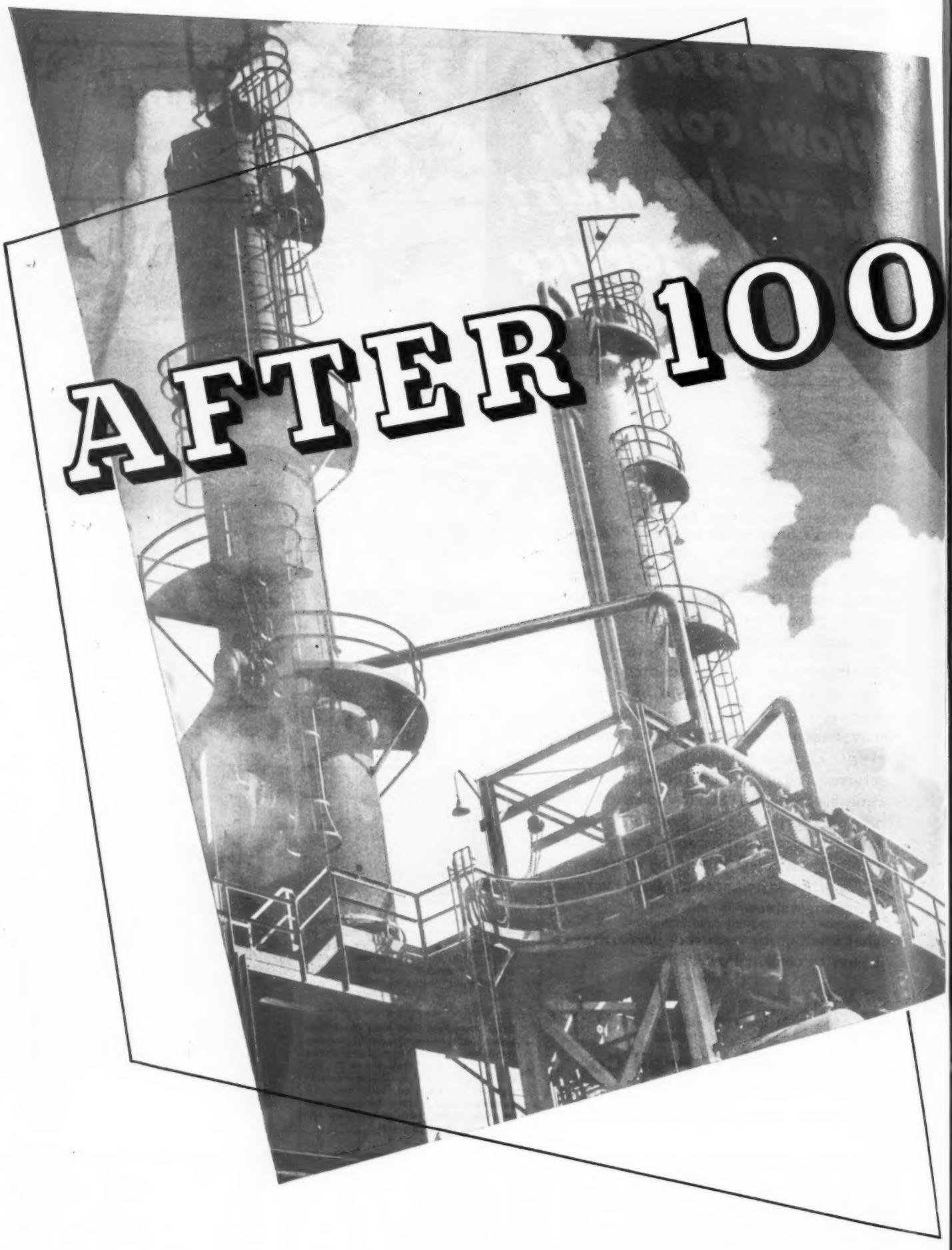
# POWELL VALVES


AFTER 100

# OCTANE, *What?*

Between 1941 and 1945 the American Petroleum Industry performed one of the greatest industrial miracles of all time. As the world knows, it was the quantity production of 100-octane gasoline. Production rocketed from a bare 40,000 barrels daily in 1941 to over 500,000 barrels daily. Even the rating 100-octane was left behind.

Today the world is waiting for other miracles from petroleum, products that will serve a world of peace. Many are already in the making in research laboratories. And in the new processes American meters will play a dependable part as they do in so many producing and refining processes today. American Meter research, backed by 109 years of meter experience, stands ready to meet the exacting requirements of the petroleum and chemical industries for the measurement, control and analysis of gases and liquids.

AMONG THE MANY AMERICAN METER COMPANY PRODUCTS FOR APPLICATION IN THE PETROLEUM AND CHEMICAL INDUSTRY ARE

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TABLE 1—Benzene Yields from Methane Using Various Halide Promoters

| Methane rate, liter/hr. | Percent catalyst | Reaction time, secs. | Temp., °C. | Total pres. Atmospheres | Mol percent light oil (mainly benzene) |
|---|---|---|---|---|---|
| 15.0 | None | 120 | 890 | 1 | Trace |
| 13.5 | 3% $SnCl_4$ | 69 | 876 | 1 | 5.5 |
| 60.0 | 21% $SnCl_4$ | 25 | 925 | 1 | 7.5 |
| 21.4 | $PbCl_2$[a] | 63 | 925 | 1 | 3.1 |
| 11.8 | $PbCl_2$[a] | 76 | 923 | 1 | 4.6 |
| 10.0 | 20% $HgCl_2$ | 113 | 775 | 1 | 6.9 |

[a] $PbCl_2$ was used in the form of a liquid bath containing an excess of $PbCl_2$ and the methane was bubbled through the bath.

When liquid halides which are non-volatile under the operating conditions are used, it is often desirable to employ a large excess of the halide in the form of a liquid bath as was done with $PbCl_2$ above. In this way the excess halide not reduced, as well as the liquid reduction product, may serve as a direct heat exchange medium for the hydrocarbons.

C., and the rate being sufficient to cause complete reduction of the halide to hydrogen chloride, the ratio of induced to non-induced reaction was 1:3. Lower halide concentrations increased the ratio, so the preferred concentration of the promoter is below 10%.

Table 1 shows some data cited which give the yield of light oil (mainly benzene) obtained when various halide promoters are employed. It would seem that, for commercial success, the process should be accompanied by cheap metal recovery and halide reconversion.

## Header Supports for Furnaces

IT HAS been common practice in constructing tube chambers in furnaces, particularly in the radiant section, to support the sets or banks of tubes and the individual tubes of the sets or banks by tube sheets and intermediate hangers exposed to the effects of heat and gases in the combustion chamber. These tube sheets and hangers had to be constructed of expensive special alloys to enable them to resist the heat and corrosion encountered. By eliminating the use of end alloy tube sheets protecting the header boxes, header box supports and supporting the tubes, a large part of this cost would be avoided.

In its U. S. 2,412,568, Standard Oil Development Co. provides a constructional arrangement in the radiant section whereby the tubes are supported at their ends in such a way that the relatively expensive alloy tube sheets are replaced by less expensive refractory and the return headers are shielded from the direct heat of the furnace and are protected from the action of the flue gases. Also, the supports are so arranged that the tube headers, supports, chamber wall, etc. may move relative to one another when expanding or contracting, without strains or stress leading to deterioration and breakdown.

As can be seen from Fig. 2, the portion of the furnace structure chosen for illustration comprises side wall 1, end walls 2 and 3, and roof 4 forming the usual combustion section of a furnace. Disposed across the combustion space are roof tubes 5 which terminate in the customary type of return headers 6. These return headers are enclosed in a housing 7 provided with hinged doors 8 which permit ready access to the fittings, header boxes, and the like.

This housing may be attached to the furnace in any suitable manner; for example, it may be attached to the furnace wall by means of supporting I-beams 9 and brackets 10. That portion of the housing nearest the furnace interior is constructed of a suitable refractory material forming wall 11 which serves to screen the housing, the headers, and other fittings contained therein from the effects of the radiant heat of the furnace and from the combustion gases.

This wall is preferably supported on top of the usual furnace wall 3 and is connected to the roof 4 through I-beam 12, although it may be simply a continuation of wall 3. The wall 11 may also be additionally suported by means of steel plate 13.

Where tubes 5 pierce through wall 12, the opening between the tubes and the refractory brick may be sealed in any desirable manner as by asbestoes rope packing 14.

The tube headers may be supported in the housing by resting them on rollers 15 which are in turn supported by angle-iron supports 16 resting on I-beam 17, or they may be supported in any other desirable manner, such as by U-bolts or J-bolts, so that the headers are free to expand or contract with the tubes in accordance with the change in temperature and conditions in the combustion zone of the furnace.

## Selected Patents of the Month

**U.S. 2,413,184** (Porocel Corp.)—Metal aluminate adsorbents.
**U.S. 2,413,185** (Porocel Corp.) — Removing volatile metal halides from fluids.
**U.S. 2,413,188** (Standard Oil—Ohio) — Lubricant for maintaining desirable body and clean metal surfaces under heat and drastic usage.
**U.S. 2,413,199** (Atlantic Refining)—Sulfonates.
**U.S. 2,413,205** (Phillips Petroleum)—Dehydration of hydro-halogen acid by distillation.
**U.S. 2,413,245** (Union Oil)—Azeotropic distillation of toluene.
**U.S. 2,413,262** (Union Oil)—High compression motor fuel containing isooctane and aromatic amine.
**U.S. 2,413,271** (Texas) — Catalytic conversion.
**U.S. 2,413,278** (Amer. Petroleum Institute)—Bacteriological process for treating fluid-bearing earth formations.
**U.S. 2,413,310** (Universal Oil Products)—Recovering hydrocarbons from sludge.
**U.S. 2,413,311** (Standard Oil Development)—Purifying acid treated (white) oil.
**U.S. 2,413,312** (Shell Dev.)—Catalytic Finishing of gasolines.

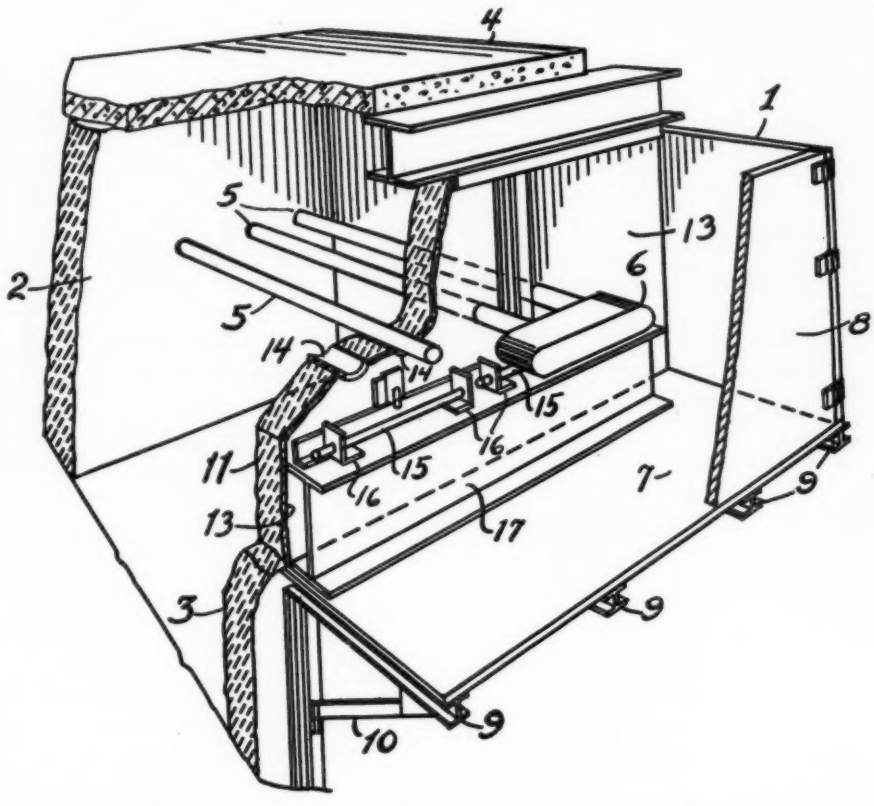


**Fig. 2—Return header support for furnaces eliminating expensive alloy tube sheet (U. S. 2,412,568)**

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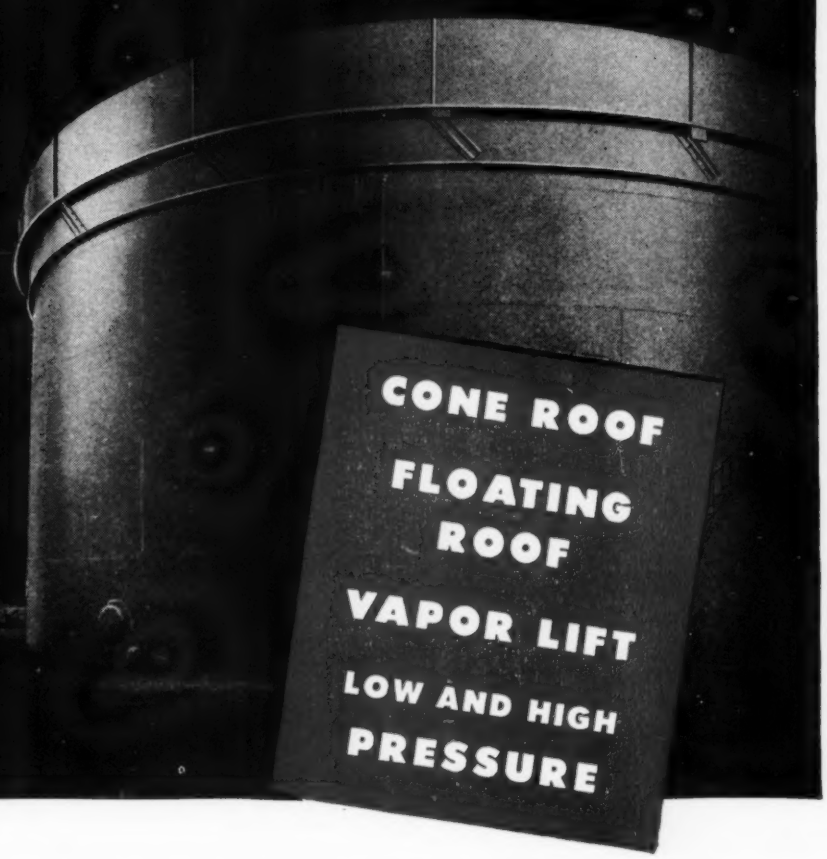


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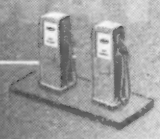

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# Light Weight Waste Heat Boiler Is Economical for "Cat" Crackers

In addition to the light weight waste heat boiler used on Catalytic crackers described below, this month's review of new and improved devices used in petroleum processing and handling operations on which patents have recently been issued include:

- ***A catalyst flow method by inbending slots on trough***
- ***Tank vent that combines mechanical and liquid seals***
- ***Airplane crash fire fighter adaptable to running oil fires***
- ***Oil drum unloading device for one-man operation***

A WASTE HEAT economizer, designed with fin type tubes, is claimed to be particularly adaptable for use on catalytic cracking units, where its light weight would reduce substantially the amount of supporting steel structure normally required.

The unit is said to have a heat exchange surface with approximately 6 times the capacity of bare tubes without the extended surface. This gives efficient duty with a small number of tubes, effecting substantial economies in both size and weight of the unit.

For example, it is said that an economizer having 20 extended surface tubes will deliver the service of about 100 bare tube heating elements, and the weight of the bare tube type unit would be 4 times as great. In addition, the arrangement of the heating space and the tubes, with no baffles, produces a minimum pressure drop between inlet and outlet ports and a corresponding minimum back pressure to the passage of heating gases.

One modification in the design of the invention is shown in Fig. 1. Flue gases enter at 11 and leave at 27. Tubular elements are indicated generally at 22a, 22b, and 22c. Sections 22a and 22b are bare tube surfaces and are designed in that way so as to obtain more even distribution of the gases over the exchanger surface and better heat distribution. Types of surface other than fins may be used, such as spiral fins or pin type.

A hinged cover 17 is included to permit easy and rapid removal of tubes for repairs or cleaning.

U. S. 2,416,273, issued Feb. 18, 1947, to John S. Wallis and John W. Throckmorton, assignors to Petro Chem Process Co., Inc.

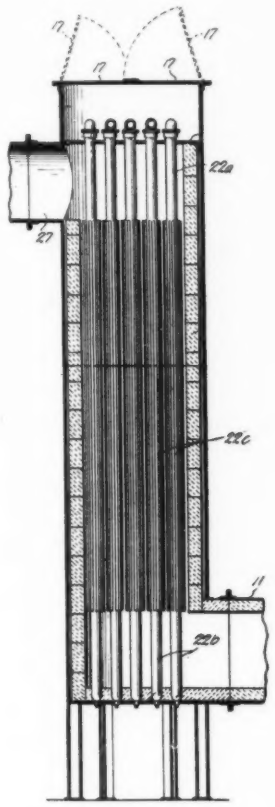


**Fig. 1—Light weight waste heat economizer (U. S. 2,416,273) utilizes extended surface tubes of the fin type to reduce the number of tubes required and the weight of the unit itself**

## Catalyst Flow Is Improved By Inbent Slots on Troughs

IMPROVED FLOW of catalyst in a moving bed catalytic cracking unit is said to result from the proper design of inverted troughs at inlet and outlet orifices on vapor tubes. The improved flow increases the active catalyst capacity of the unit.

A front and an end view of the trough is shown in Fig. 2. The vapor tube is indicated by 15, orifice by 17, and trough by 16. In addition to flow area for gases under the open bottom of the trough, slots are provided, as at 21, by depressing inwardly a portion of the sidewall, 20.

The width of this slit may be varied. In troughs with steeply sloping sidewalls, the opening may be much greater than the particle diameter without danger of passage of catalyst.

The inbent feature is of paramount importance, it is said. Experimental observations of flow of solid particle-form catalyst over both inbent and outbent slots have shown clearly a contrast, as indicated in Fig. 3 at A and B.

At A, there is shown an area 23, above the outbent slot 24, where a very serious collection of "dead" or non-flowing catalyst exists, almost regardless of the form or positioning of the shoulder 25. On the other hand, the inbent type of slot shown at B not only presents no restrictive shoulder, but has been found by observation to present no dead area of non-flow.

U. S. 2,416,165, issued Feb. 18, 1947, to Louis P. Evans, assignor to Socony-Vacuum Oil Co. Inc.

## Improved Tank Vent Combines Mechanical and Liquid Seals

A LIQUID SEAL and a mechanical valve are combined to provide an improved type of storage tank vent for relieving excessive pressures or vacuums.

Because a liquid seal is most effective in keeping a vent opening vapor-tight and a mechanical seal is most effective during periods of vapor release, the two types are

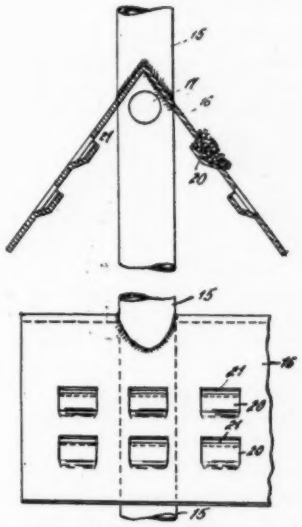


**Fig. 2—Improved inverted trough for vapor tubes in moving bed catalytic cracking unit (U. S. 2,416,165). Vapors flow under trough and also through inbent slots in trough side walls**

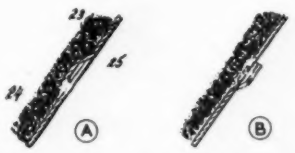


**Fig. 3—Comparison of flow through two types of slots. Dead spaces of non- or slow-flow occur with outbent type slot as shown at A, while catalyst flows freely with inbent slot as at B**

combined in a single unit, mounted on a tee-fitting on the storage tank vent pipe.

Previous designs of pressure-vacuum valves, it is pointed out, have generally been of either of the two types, liquid or mechanical. The liquid seal is ideal because liquid readily takes the shape of its container. However, liquid is easily separated and broken into droplets when air or vapor is bubbled through it. This is the chief objection since the liquid tends to be carried away by the escaping vapors. In addition, the density of the sealing liquid changes due to gaseous inclusions.

A mechanical valve is said to be ideal under releasing conditions because its specific gravity is constant and there is no tendency for particles to be picked up by vapors.

U. S. 2,413,804, issued Jan. 7, 1947, to Reign C. Ulm, assignor to Graver Tank & Mfg. Co., Inc.

## Airplane Crash Fire Fighter Is Adaptable to Running Oil Fires

Designed primarily for fighting airplane crash fires but said to be equally adaptable to gasoline or oil tank fires or running ground fires, a new extinguishing device combines carbon dioxide and foam in a single discharge.

The chief advantage is that reignition of combustible liquids is prevented by the foam, while safe areas for maneuvering are quickly produced by the relatively rapid action of the $CO_2$.

A mobile type unit, mounted on the front end of a truck, is shown in Fig. 4. $CO_2$, either low or high pressure, passes through pipes 11 and 12 to discharge pipes running lengthwise in nozzle 9. The nozzle is designed to produce a stream of combined snow and vapor with the snow forming the central portion of the stream and the vapor the outer edges. This type of stream has been found extremely effective in combatting outdoor fires in high winds.

Conventional aspirators at 23 form mechanical foam from the supply line 21. The foam is discharged via pipes 10 into the core of the $CO_2$ stream so that it intermixes thoroughly with the gas and snow. Chemical type foam nozzles may be substituted for the aspirators if desired.

Separate control valves on the supply lines for each extinguishing agent provide facilities for fighting a wide variety of fires. All $CO_2$ and no foam, through various proportions of the two components, to all foam and no $CO_2$ are obtainable with the unit.

As an example of the capacity of the apparatus, it is said that ground coverage of about 10 ft. wide by 30 to 40 ft. long can be attained under the following specifications:

1. Apparatus is about 3 ft. above the ground.
2. $CO_2$ discharge nozzle is inclined 23° toward, and foam guns are inclined 3° from the ground level.
3. $CO_2$ nozzle measures about 7 ft. long and 8 in. deep.
4. $CO_2$ discharge rate at nozzle is 1200 lbs./min.
5. Discharge capacity of the four foam guns is about 100 gals./min.
6. The liquid $CO_2$ is maintained at its source at 300 psi.
7. Foam solution is delivered to guns at 90 to 120 psi.

U. S. 2,414,683, issued Jan. 21, 1947, to Hilding V. Williamson, assignor to Cardox Corp.

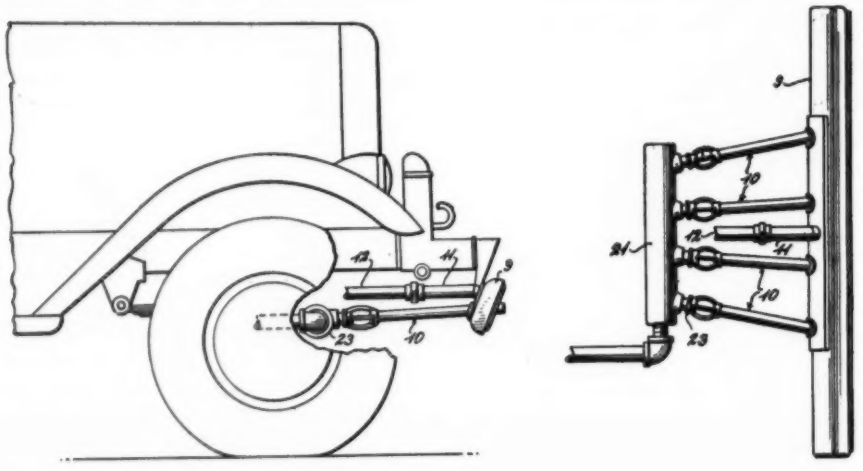


**Fig. 4—Fire-fighting apparatus which discharges combined stream of carbon dioxide and foam (U. S. 2,414,683). Foam blanket prevents reignition of running ground fire first quickly extinguished by carbon dioxide**

## Oil Drum Unloading Device Makes It a One-Man Job

Oil drums can be unloaded by a single operator from trucks, freight cars or other raised platforms to the ground with a specially-designed locking device mounted on a skid.

The unloader is shown in general view in Fig. 5, placed for use at the tail gate of a truck.

However, it may be used similarly at the side-door of a box car or at a freight loading dock. Designed for quick handling of drums in war time, it is equally adaptable to plant operations in peace time.

A detailed view of the sliding drum carriage is shown in Fig. 6. In operation, the drum is rolled from the truck floor up the incline 13 into position on the carriage. It rests against board 30 and on the upper half of the pipe framework 48, which is mounted so as to rock on hinge 51.

Board 40 of the carriage extends under slide board 12 of the skid so as to keep the carriage in place but free to move up or down the skid. The workman controls the motion of the drum on the carriage by means of applying varying degrees of tension on the cable 54, which is attached to the carriage at 53.

When the carriage reaches the ground level, the board 35 strikes a chock on the slide 12, jolting the drum over the support board 30 when the operator releases tension on cable 54.

U. S. 2,414,447, issued Jan. 21, 1947, to Paul J. Cargile, United States Navy.

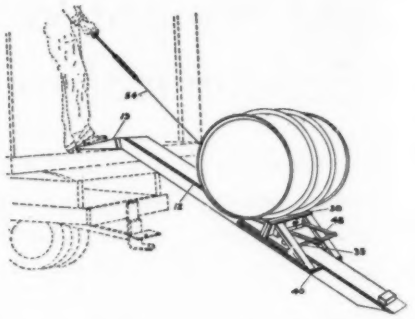

**Fig. 5—Oil drum unloading device which permits one man to transfer drums from raised platforms to the ground (U. S. 2,414,447). Carriage 11 is firmly secured to skid 12, although free to slide up or down**

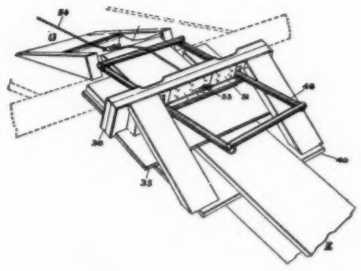

**Fig. 6—Detailed view of slidable carriage on drum unloading device (U. S. 2,414,447). Drum rests against board 30 and on tiltable framework 48 while sliding down skid 12**

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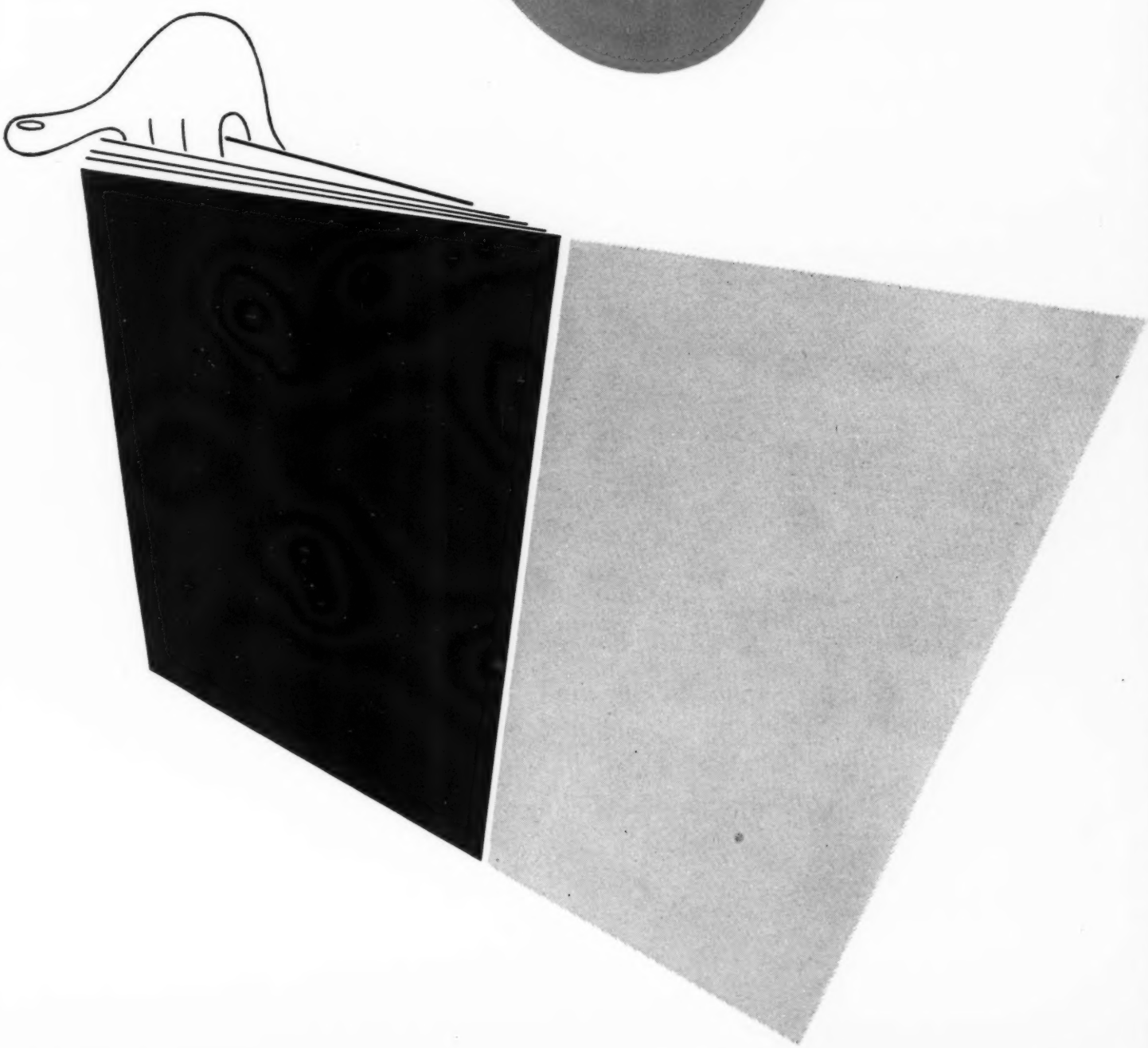

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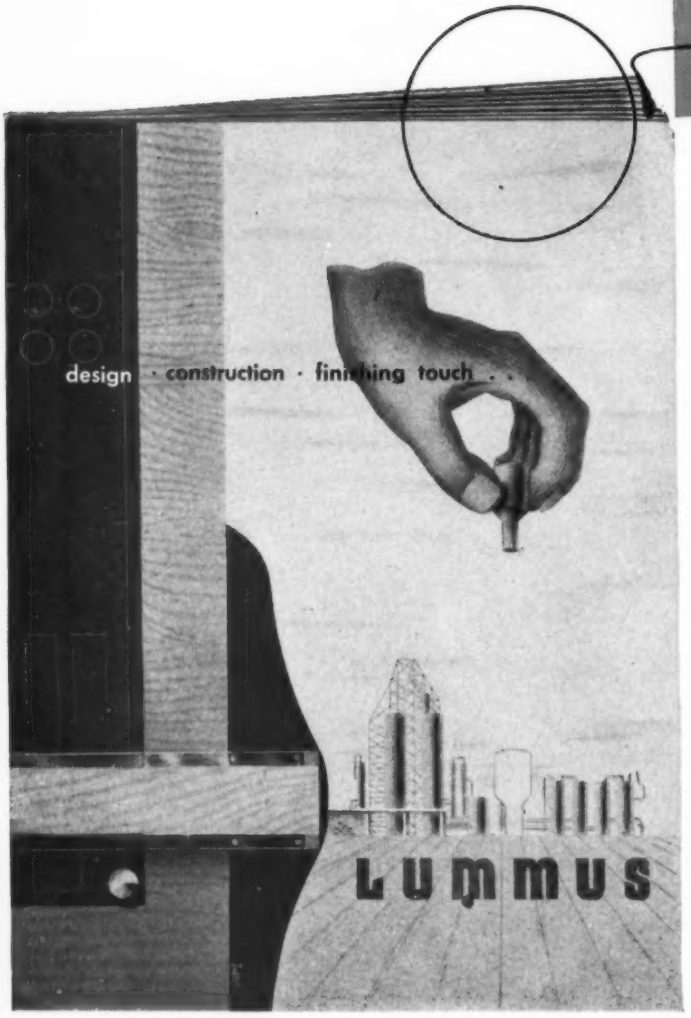


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# Remedies Studied for Freakish Corrosion Occurring in Some Condensate Fields

By D. P. THORNTON, Jr.

*Assistant Editor*
*PETROLEUM PROCESSING*

**Three years' study of the cause of the spotty attacks corrosion experienced in gas-condensate fields indicates that lower fatty acids found in well fluids in minute concentrations is a principal promoting agent. Various types of chemical inhibitors are being tried with varying degrees of relief, emphasizing the capricious nature of this type of corrosion. Plastics or other forms of coating for tubing and other equipment are being tried out. The investigating work sponsored by the Natural Gasoline Association is to continue.**

THE mystery of the corrosion of equipment which takes place in certain gas-condensate wells is beginning to yield some of its secrets after nearly three years' investigation by the Natural Gasoline Association of America.

Tubing, casing, wellhead connections and flow lines were being rapidly destroyed by an unknown corrosive agent in some wells, while other nearby wells producing from the same formation were untouched. The task of determining the causes of this highly selective form of corrosion was entrusted April 12, 1944 to the NGAA's Corrosion Research Project Committee. It was also to discover if there was potential or actual corrosion damage occurring in cycling plants handling distillate from the corrosive wells.

### Oil Companies Finance Study

The NGAA committee is composed of technical representatives of 26 oil companies who are financing the corrosion study. It also has the cooperation of special groups from the American Petroleum Institute and the National Association of Corrosion Engineers. The work done to date on the project indicates that:

1—At least one cycling plant has been attacked by the same form of corrosion that occurs in the gas-condensate wells.

2—The majority of distillate formations are corrosive and the balance potentially so.

3—New distillate fields likely will be corrosive, or will become corrosive in later life, especially if cycled.

4—The iron content of well fluids is not a direct means of judging the extent of corrosion; fluctuations correlate directly with changes in *amount* of corrosion.

5—The corrosive agents are carbon dioxide and water, probably catalyzed by trace amounts of fatty acids naturally present in well fluids. However, the presence of one or all these chemicals is no indication that the field is or will become corrosive.

6—Natural inhibitors can and do exist.

7—Certain chemicals injected into the well possess inhibiting power under some conditions. Others may plug flow strings or are objectionable in plant processing and marketing of the distillate product.

The problem of corrosion in gas-

### *NGAA Corrosion Research Project Group*

**The Steering Committee for the research program on corrosion of equipment in gas-condensate wells sponsored by the Natural Gasoline Association of America consists of the following group from the general NGAA Corrosion Research Project Committee:**

**T. S. Bacon,** Lone Star Producing Co., Dallas; Chairman and General Chairman of the Project Committee.
**J. M. Dillon, Jr.,** Shell Oil Co., Houston.
**C. F. Bedford,** Stanolind Oil & Gas Co., Houston.
**M. E. Holmberg,** Phillips Petroleum Co., Bartlesville, Okla.
**W. H. Justice,** Tide Water Associated Oil Co., Houston.

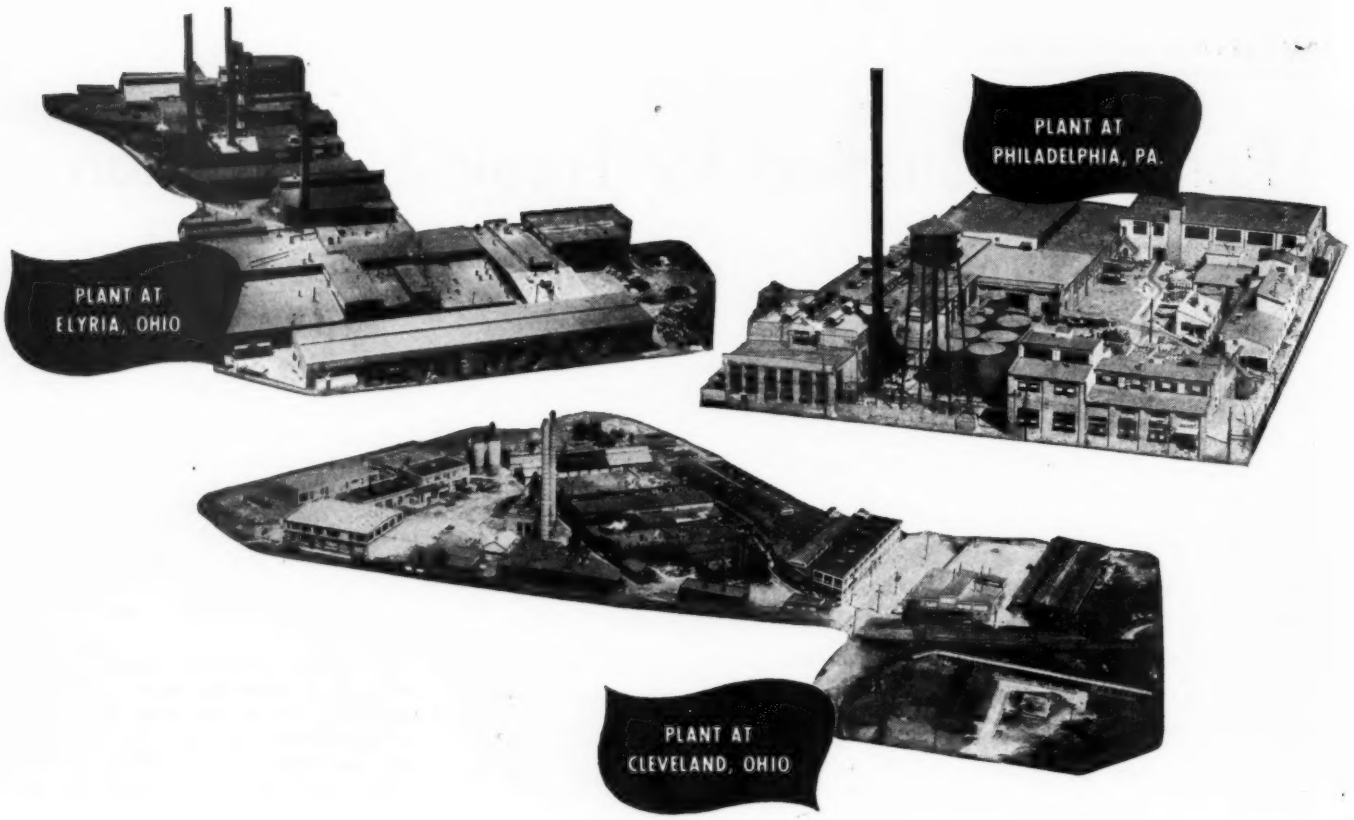
Chemical Advisory Committee:
**E. C. Greco,** United Gas Pipe Line Co., Shreveport, Chairman
**Dr. W. Z. Bruce,** Carter Oil Co., Tulsa.
**C. K. Eilerts,** U.S. Bureau of Mines, Bartlesville, Okla.
**Paul Menaul,** Stanolind Oil & Gas Co., Tulsa.
**Dr. D. A. Shock,** University of Texas, Austin.

**Following are the companies contributing to the corrosion research program from whom a personnel of about 75 are active in the program:**

J. S. Abercrombie Co.
Arkansas Fuel Oil Co.
Arkansas Louisiana Gas Co.
Carter Oil Co.
The Chicago Corp.
Continental Oil Co.
Cotton Valley Operators Committee on Distillate Production
Gulf Oil Corp.
Gulf Plains Corp.
Humble Oil & Refining Co.
La Gloria Corp.
Lone Star Producing Co.
Magnolia Petroleum Co.
Ohio Oil Co.
Phillips Petroleum Co.
Shamrock Oil & Gas Corp.
Shell Oil Co., Inc.
Standard Oil Co. of California
Stanolind Oil & Gas Co.
Sun Oil Co.
Superior Oil Co.
The Texas Co.
Tide Water Associated Oil Co.
Union Producing Co.

**Also cooperating with research:**

Chemistry Department, University of Texas.
Bartlesville, Okla. Station, U.S. Bureau of Mines.

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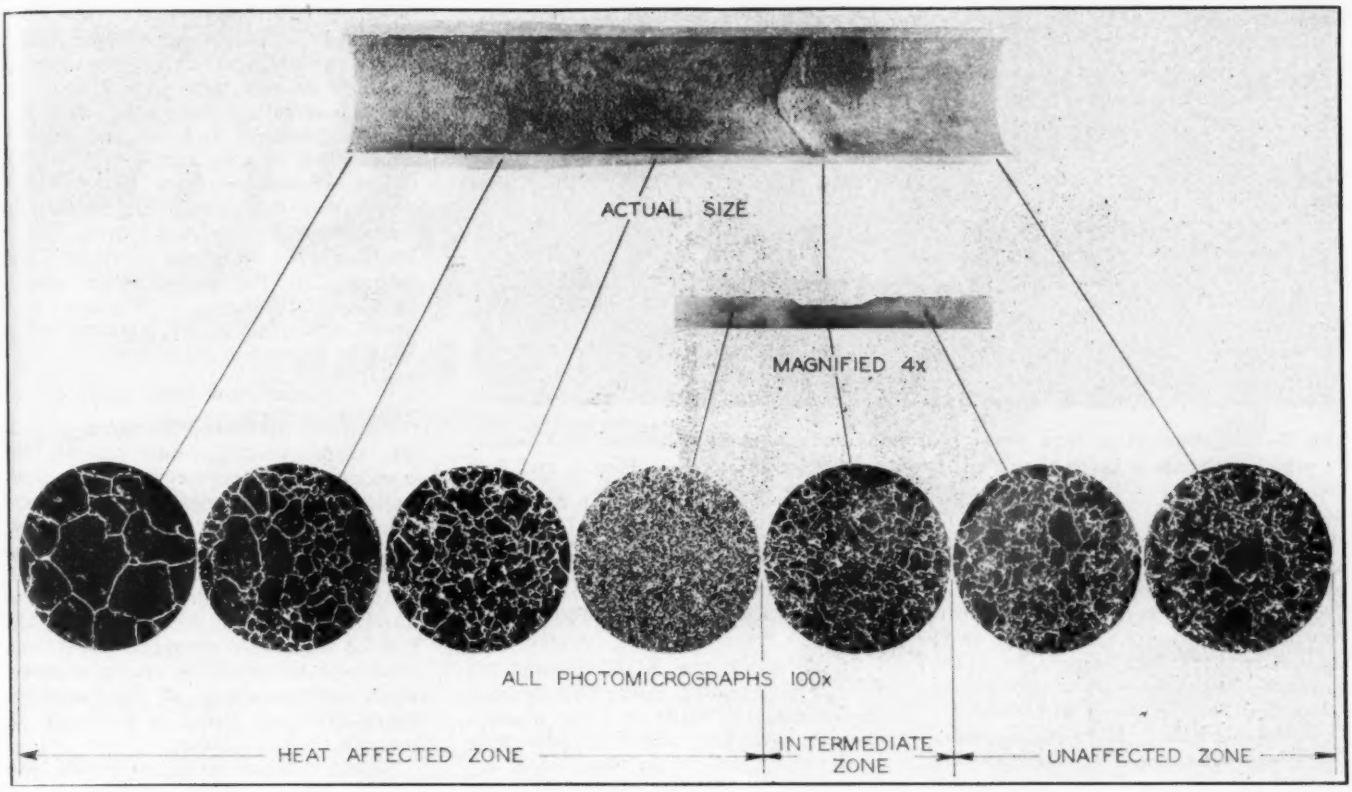


**Fig. 1—Appearance of distillate well tubing exhibiting "ringworm" corrosion and photomicrographs of various sections showing grain structure. In this case corrosion was exhibited near the end of the tubing and extended over the entire circumference. The tubing was not normalized after upsetting**

condensate wells is by no means solved and the NGAA Committee's intensive investigation continues, supplemented by private work of individual oil companies.

The exact nature of the promoting fatty acids and the full mechanism of the corrosion reaction have not been explained, neither have the natural inhibitors been fully identified. In at least one case hydrogen sulfide has been involved as a corrosive agent but its presence in most other cases, as well as that of oxygen, has been definitely ruled out. A question of metallurgy also is involved. Many alloys have proved useless as a corrosion preventive, or nearly so, while others show promise.

### Committee Spends $41,000

Approximately $41,000 has been spent by the NGAA Committee so far in the work, which does not include that of privately-financed investigations. In the Katy Field, near Houston, alone the average annual loss due to this form of corrosion is estimated in excess of $200,000, and the corrosion bill at Cotton Valley is placed at 47c per million cubic feet of gas.

Some of the additional drilling programs, necessitated to re-complete wells in corrosive fields, may cost more than $1,000,000 per field, at the rate of $150,000 upwards for the average 10,000-ft. well. To this can be added the bill for frequent reworking of wells, and for bad luck with fishing jobs, damage to casing and possible damage to the formation from mud and water.

The corrosion attack in the gas-condensate wells has been almost capricious in its variegated aspects. There is no way of forseeing where or when it will attack or what forms will be exhibited. Among reported attacks are the following random examples: Of two wells in the same formation, perhaps side by side, one will be severely attacked and the other untouched. A distillate field several years old and with no evidence of trouble suddenly became corrosive in certain parts when cycled gas reached the producing wells. Tubing may be uniformly corroded over its entire 10,000 ft. length, or pitted severely only at joints. Corrosion may extend only to 5000 ft. or attack may appear only below the 5000-ft. level. Some joints may be severely damaged, intervening joints untouched. In still other cases the action may take peculiar shapes, often almost perfectly shaped rings around the tubing wall, eating out long longitudinal valleys or forming small continuous cuts having a worm-eaten appearance, see Fig. 1.

Extreme cases of corrosion have frequently been found in meter runs and flow lines. The well choke often may be attacked most severely of all, probably a combination of corrosion and erosion. The flow line may not be attacked near the well, but corrosion may show up perhaps a half mile away. An instance of this kind is shown in Fig. 2. Metallic ring gaskets, pipe nipples and valve trim on Christmas trees have been severely damaged in a short time.

In some wells the tubing will be severely attacked, Fig. 3, yet wellhead and flow line equipment will be immune; this may be reversed in another well. Internal corrosion of casing and external corrosion of tubing have been noted in some dually-completed wells. Casing is believed corroding externally in some fields from electroyltic attack developing from electric currents generated in field lines and galvanic corrosion also has been noted in Christmas tree fittings and flow lines.

### Cycling Plant Corrosion Negligible

Cycling plant corrosion as yet has been regarded as negligible. According to Buchan[1] it is potentially serious enough at the Katy plant of Humble Oil and Refining Co. to warrant periodic inspections. On this point the NGAA committee is silent in its conclusions but F. S. West[2] states "there is no reason to believe that the cycling plant equipment, especially that equipment handling produced well liquids, is immune from such corrosion, even though it is logical to believe the action should be less severe within the plant than at the well." Until recently, most of the work on the problem has been laboratory investigations by the various groups involved. Field work largely has been carried on by individual companies and doubtless will continue. Coupons of various metals and alloys have been exposed

**Fig. 2—Corrosion in a lead pipe. Note the distinctive difference in this attack, which presents a herringbone appearance, to that exhibited in Figs. 1 and 3**

in both corrosive and non-corrosive wells and yields and very important differences have been found in their resistance.

Of the known corrosive agents, carbon dioxide and water (as carbonic acid) is considered to be the prime cause of the corrosion. Experiments by the Bureau of Mines and Battelle Memorial Institute[3] have indicated that carbonic acid, under conditions comparable to those existing in the well, will corrode mild steel 0.030 in. per year. (The wall thickness of 3-in. extra heavy steel pipe is 0.304 in. and, at pressure of 1500 to 3000 psi existing in the average distillate well, would fail in less than ten years even if pits were not formed.)

The attack rate may be increased in the presence of the lower fatty acids in concentrations known to be present in the well fluids. Laboratory attack rates are less than one-tenth the maximum actually found in the field, although areas showing extremely high rates in the field have been exposed to excessive turbulence, such as exists in chokes, at ells and tees. Thus the committee assumes that carbonic acid, and lower fatty acids in concentrations up to 1000 ppm as propionic acid, are the villains.

### X-rays Feature Recent Studies

Much recent work[4] has revolved around X-ray studies of films formed on metal coupons by the well fluids and chemical analyses of well fluids to determine the concentration and identity of the fatty acids present. Detection and identification of the natural inhibitors believed present in some fields also is receiving close attention. These investigations are extremely difficult, since certain organic compounds present in concentrations as low as 0.001% might be effective in modifying any protective film formed, consequently affecting mode and rate of attack.

If success crowns this recent work, it will be possible to predict the dregree of corrosiveness of new wells or fields from analyses of well fluids, and well completions will be planned accordingly. This information also should indicate what compounds or classes of compounds should effectively inhibit the type of corrosion expected. It already is possible to follow the effect of mitigating treatments in individual wells by analysis of well fluids, particularly the variations in iron content.

D. A. Shock, the NGAA committee's field representative, and Dr. Norman Hackerman, University of Texas physical chemist, have done most of the film study work under fellowship established by the NGAA at the University. Together the two have developed a successful method of adsorbing acidic constituents in the hydrocarbon phase of the well fluid on silica gel and extracting them for laboratory study[5]. These materials are supplied to Dr. H. L. Lochte for natural inhibitor studies under another fellowship at the University.

Reports so far from the general investigation indicate that the possibility of finding some inexpensive alloy to resist the corrosive attack is nearly "hopeless." Test coupon studies reveal that nothing less than 18-8 stainless steel can be depended upon to do the job, and even this class of alloys is slightly attacked. Chromium contents of less than 9% are no better than mild steels. High tensile bronzes have shown some promise, however. Monel flow-beans and valves trimmed with it as well as some of the Stellites have been successful. Even metal plated strings have been run in field tests which are as yet inconclusive.

Much of the metallurgical work in the investigation has been done by Battelle Memorial Institute and more is in progress in cooperation with a corrosion committee from the National Association of Corrosion Engineers. This committee is supplying seven bombs containing 32 different alloys for field testing. The Bureau of Mines also is making laboratory investigations on alloys and platings in addition to its studies of chemical inhibitors.

### Plastics Now Used More

Corrosion prevention by means of various plastic coatings until recently has been considered unpromising. Any coating of this type must withstand considerable erosive action without wear, be capable of surviving normal setting and pulling of tubing without damage, resist wear from running of tools or instruments through the tubing in place and be impervious to gases under high pressure. According to the committee, most coatings, either of the painted-or baked-on types, failed to meet one or more of these conditions.

Recently, however, improvements have been noted in plastics. Buchan[1] reports that a baked-on (at 350° F.) thermosetting and thermoreacting plastic of the phenol-formaldehyde (Bakelite) type, applied in several layers to a total thickness of 0.005-0.006-in., was used on tubing strings in a Louisiana field where bare-metal tubing failed within three to four years from corrosion. Conditions there are similar to Texas Gulf Coast condensate fields. Although length of exposure is not given, this material had not failed in the Louisiana trials upon last inspection. This coating now is being tried in several wellheads and other fittings on wells of the Katy field and had not failed when examined five months after installation. It now is on trial in four more wells there.

Several authorities[1,3,4,] have pointed out that a successful plastic coating metal plating or alloy has possibilities as

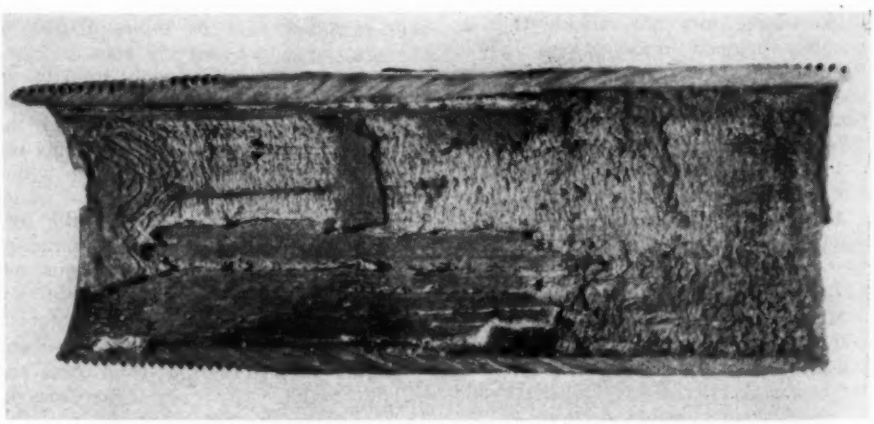

**Fig. 3—Corrosion in a tubing hanger taken from a distillate well. In this case the attack was especially severe**

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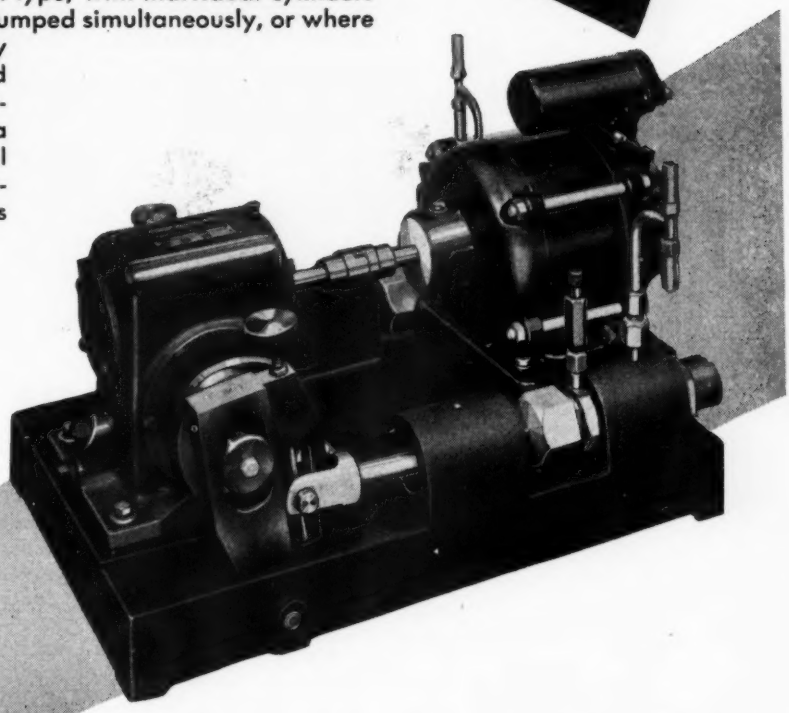

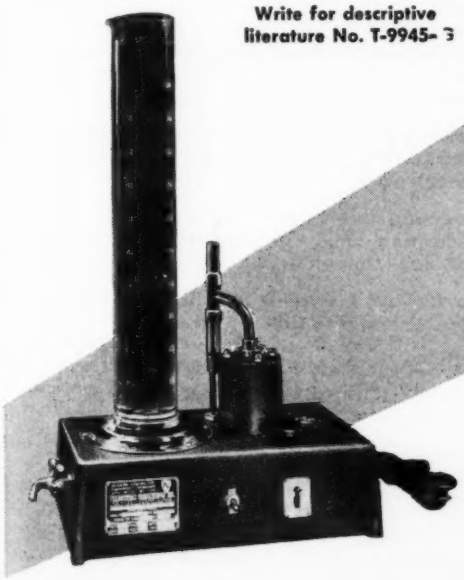

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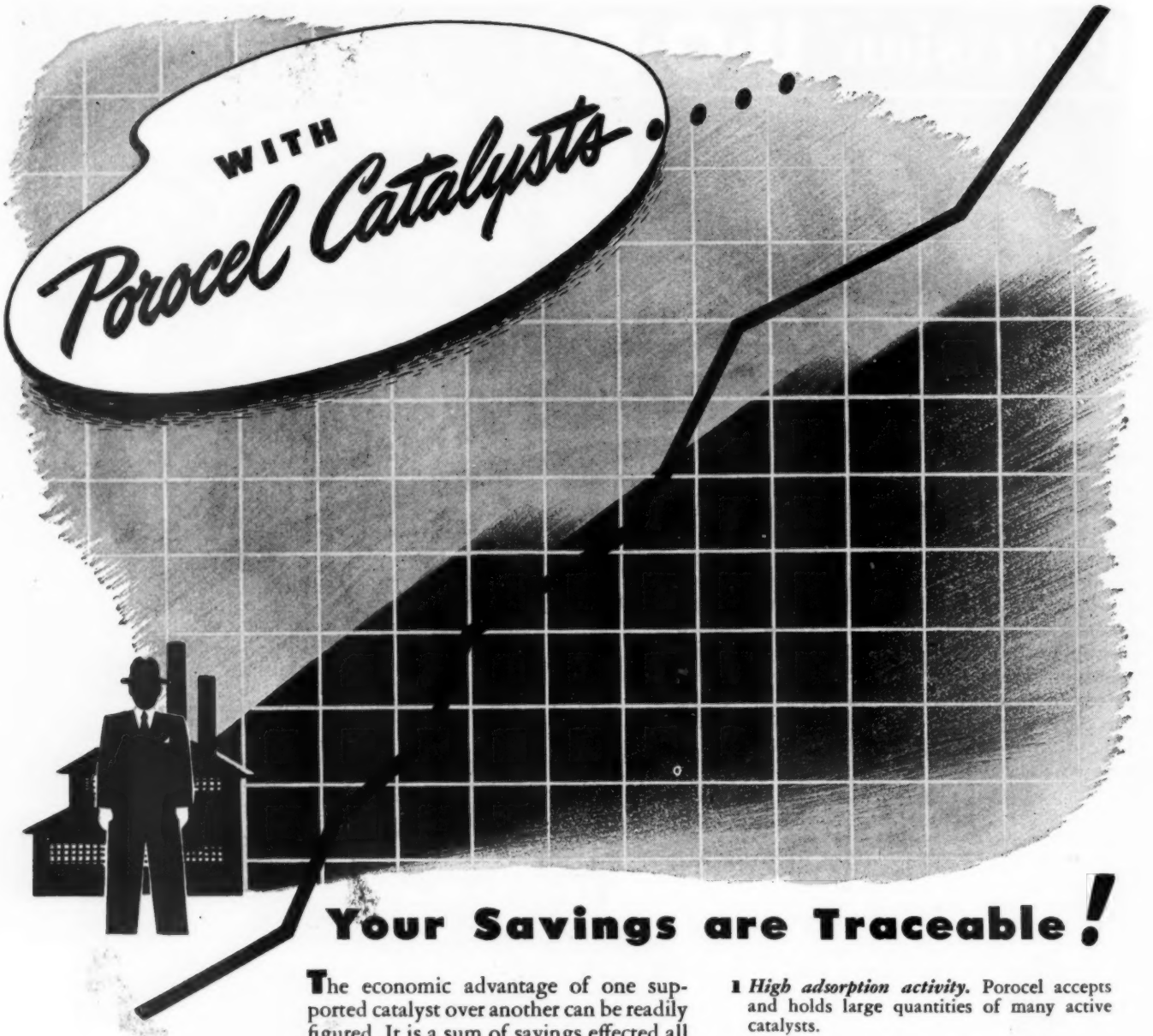


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a means of combatting this corrosion. At Katy, for example, all the tubing in producing wells could be coated with plastic for about $140,000, which is approximately the annual work-over expense due to tubing corrosion. If the coatings extend tubing life but one year, they would thus pay out in comparison with unprotected tubing. If life could be extended five years, coated pipe probably would be the most satisfactory method of handling the problem of subsurface corrosion. A similar case can be made for plated and alloy tubing.

The search for chemical compounds which could be injected into the well to control the corrosion has met with varying degrees of success. A number have been tried and from these experiences it is postulated that probably no single compound will be found which will work in all fields or formations (3,4,6,), because of the differing conditions peculiar to many individual fields.

The committee's work on the selection of inhibitors shows that some chemicals might plug the flow string, either by chemical action in precipitating such ions as calcium and magnesium from the produced connate water or by evaporation of treating solution water at the relatively high temperature involved. This is particularly true with inhibitors containing sodium salts, or those tending to raise the alkalinity (pH) of the well liquid.

Others, which might work well in inhibiting corrosion, may prove too objectionable for other reasons. In this class, for example, are bone oil and sulfur compounds. Bone oil particularly was not liked because of its exceedingly offensive odor, which became noticeable during processing of the distillate.

Ammonia is in successful use in treating wells, although considered inadvisable by some authorities because of its detrimental effect on Admirality metal equipment in the cycling plant. Formaldehyde similarly is not favored by others because of its tendency to polymerize and foul such tubular equipment as propane chillers.

Naphthenic acid is being used experimentally at two wells at Cotton Valley, sodium chromate solution in another. Seventy-five gallons of a solution of 5 lbs. chromate (costing 17c per lb.) in 100 gal. water is controlling corrosion effectively although the present method of continuous injection via chemical pump is considered expensive. Naphthenic acid (costing 90c per gal.) in proportion of one part to 19 parts of mineral seal oil (obtained from the cycling plant at zero cost), injected by gravity-type lubricators, has reduced corrosion to a negligible point in one well and to 50% in the other, according to early but inconclusive tests reported to the committee(4).

In some cases, simple neutralization by continuous injection of alkali into the casing annulus (provided the well is not completed as a dual-producer) and producing it through the tubing is successful. Soda ash and ammonia have been injected with satisfactory results in certain wells, but plugged tubing in other distillate fields with solids precipitated from entrained connate water. Ammonia has been successful at South Jennings, Chocolate Bayou and other South Louisiana fields, also at Old Ocean, Texas.

Sodium dichromate also has proven successful at Old Ocean, Erath and is being used at Katy. Sodium chromate-soda ash injections are apparently successful at Cotton Valley, although the latter has shown a tendency toward slow plugging of the flow string. Soda ash alone is apparently successful at Katy.

Most spectacular results so far were obtained from tests of one well in the highly corrosive West Tuleta field in Texas, with a proprietary corrosion inhibitor called "Kontol 115" marketed by the Tretolite Co.(4). This is a semi-polar organic material made from a petroleum fraction, is soluble in oil and has no tendency to precipitate calcium and magnesium salts from well fluids. It is chemically attracted to metal surfaces, on which it forms an adherent, invisible protective film.

Injection of this material into the well bore via the casing annulus with a chemical pump at the rate of 0.419 qt. per million cubic feet of gas, for an approximate chemical cost of 87c per day, dropped corrosion to 7% of the original uninhibited rate as determined by corrosion of test coupons before and during injection. Moreover, other tests indicated there was a residual inhibitive effect to the extent of 50% of the original rate for up to 30 days after discontinuing injection. This last is a particularly valuable feature in that it relieves the operator from maintaining standby equipment for emergencies and may result in a reduction of treating expense by permitting periodic applications of inhibitor rather than continuous injections.

Some authorities believe the ultimate solution of the corrosion difficulties will come through tubing strings protectively coated, by chemical inhibitor injection, or a combination thereof. Knowledge of the corrosion mechanism and development of analytical methods which will permit anticipation of the type of attack to be expected will aid in setting up the rate of completion of new wells and fields. It is certain that a majority of any new fields which may be discovered will be corrosive at least to some extent. Thus the problem of handling this type of selective corrosion will remain of interest to producers and cycling plant operators.

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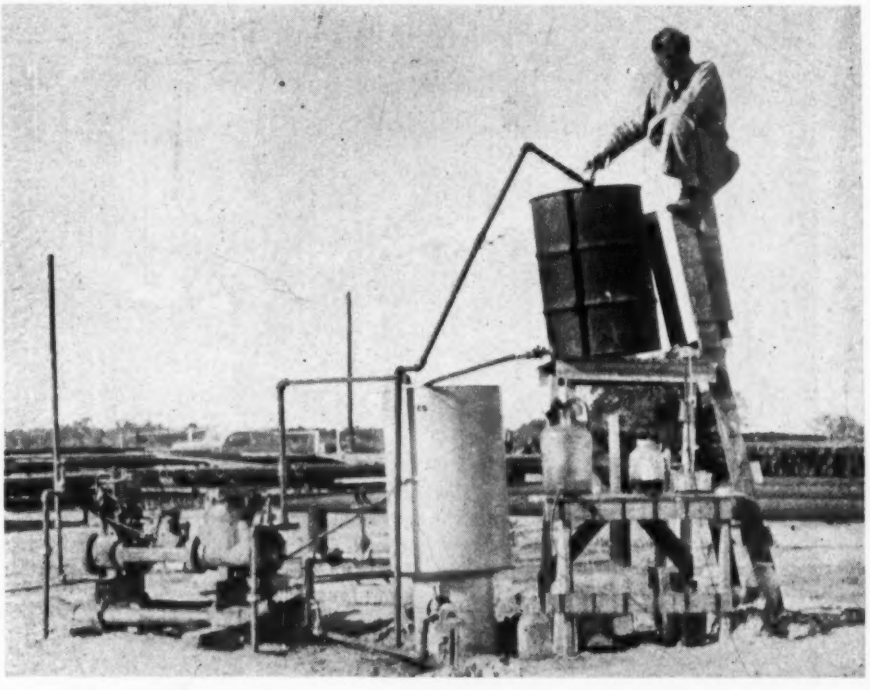

**Field apparatus for extracting 10 ppm. of fatty acids, believed to catalyze the carbonic acid corrosion in some distillate wells, from the raw effluent. D. A. Shock, NGAA field representative is shown operating the extractor**

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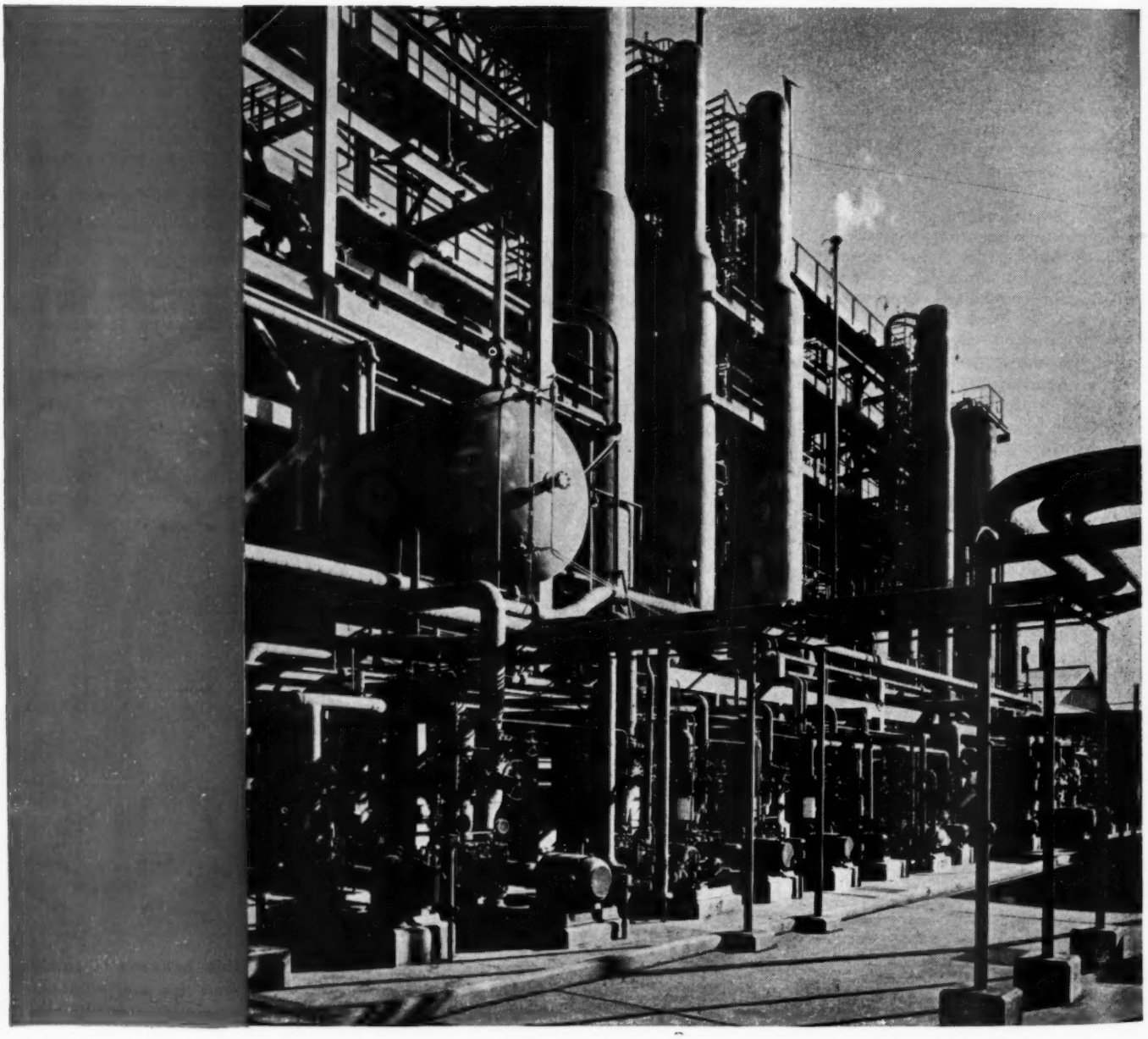

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# Four Factors Are Major Controls in Design Of an Economical Oil-Water Separator

**Article 16 in a Series**—By W. B. HART
*In Charge of Waste Disposal for Atlantic Refining Co.*

**Type of flow, shape of equipment, size and rate of rise of oil globules, and the relation of rate of rise to separator length play an important part in designing full-scale plant equipment for sedimentation method of separating oil from refinery waste water.**

**Great care is necessary in the design of accessories for reducing turbulence before flow is introduced into the sedimentation chamber proper. Flow is divided, impinged against baffles and weir controlled, then sent through a layer of Raschig rings or cinders, which breaks down water-in-oil emulsions and aids in the formation of larger oil globules, necessary for good separation. Proper functioning depends on preventing entry of stable emulsions and of particles such as plant growths, sanitary sewage or floating masses of coke.**

**Design of the sedimentation chamber and other features of the oil separator will be described in the next issue.**

IN THE preceding article it was stated that separator design is a matter of adhering to sound fundamentals, but with modified values which will give satisfactory treatment results. The basic type of flow, i.e., laminar flow, was discussed, and the reason why this is the fundamental type of flow was explained. The next step is to determine how, and to what extent, the basic flow can be modified so that a practicable sedimentation procedure can be devised, and reasonably economical equipment designed for its application.

### Certain Factors are Design Controls

Certain factors play such important roles in the design of sedimentation equipment that they may be regarded as design controls, and therefore they are the logical points of approach. These factors are as follows:

(1) The type of flow through the equipment.

(2) The shape of the equipment cross-section, i.e., the channel cross-section.

(3) The size of oil globule to be considered and its rate of rise.

(4) The rate of rise in relation to separator length for practical application.

The type of flow essential to effective separation of oil from water in such a way that the oil can be retained and collected is the most important factor in the sedimentation process. It must be free of turbulence which is powerful enough to overcome the buoyancy of the oil globule, i.e., to so interfere with the normal path of rise that the globule is carried on through and out of the equipment with the waste flow. To analyze this relationship some yardstick of turbulence must be established.

In determining the basic or laminar flow, the critical velocity for an open channel was used. This is a fixed value, however, and offers no opportunity for logical modification. But the critical velocity is derived from factors which also are used in the derivation of the dimensionless value known as the Reynolds number. This is evident from a comparison of the two equations:

$$v_c = \frac{360\nu}{R} \quad \text{and} \quad \mathrm{R} = \frac{VR}{\nu}$$

It readily can be seen from these equations that there is a certain Reynolds number for the critical velocity essential to laminar flow. This dimensionless value, therefore, appears to have all the requirements necessary as a yardstick for modifying the basic type of flow in a logical manner. It has been used as an instrument for design of models from full sized hydraulic equipment, and for comparisons of hydraulic structures. Its usefulness in connection with the matter under consideration can be etablished clearly.

The flow of water in an open channel has been described in several publications. It must be realized that the open channel flow described(166) is the flow in long experimental channels. But the type of flow which can be developed in such channels is the type of flow essential to the continuous separation of oil from water by sedimentation.

In discussing the basic type of flow, the investigations of Hopf were mentioned(164). He established that the critical velocity could be evaluated by using the equation:

$$v_c = \frac{360\nu}{R}$$

This critical velocity, under conditions which otherwise are proper, will result in laminar flow. In the Hydraulic Laboratory at Gratz it was found that when the Reynolds number $\mathrm{R} < 144$ the flow will be laminar, and when $\mathrm{R} > 900$, laminar flow cannot exist. Obviously the critical velocity as determined by Hopf is a fixed figure, while Reynolds number varies, yet is indicative normally of flow condition. This is evidenced further by Reynolds' own investigations (167). He showed by use of the equation:

$$\mathrm{R} = \frac{VR}{\nu}$$

that when $V \times R$ is equal to, or less than 0.002, laminar flow exists; when $V \times R$ is between 0.002 and 0.007, the flow may be either laminar or turbulent; and when $V \times R$ is equal to or greater than 0.007, the flow is turbulent or shooting.

That the use of Reynolds number is the best yardstick for estimating the relative degree of turbulence also is shown clearly by Reynolds original work with flow in pipes(144). He determined the upper limit of laminar flow in pipes to be of the order of 2700 to 4000, and the lower critical Reynolds number to be of the order of 2100. But by providing the necessary degree of quiescence

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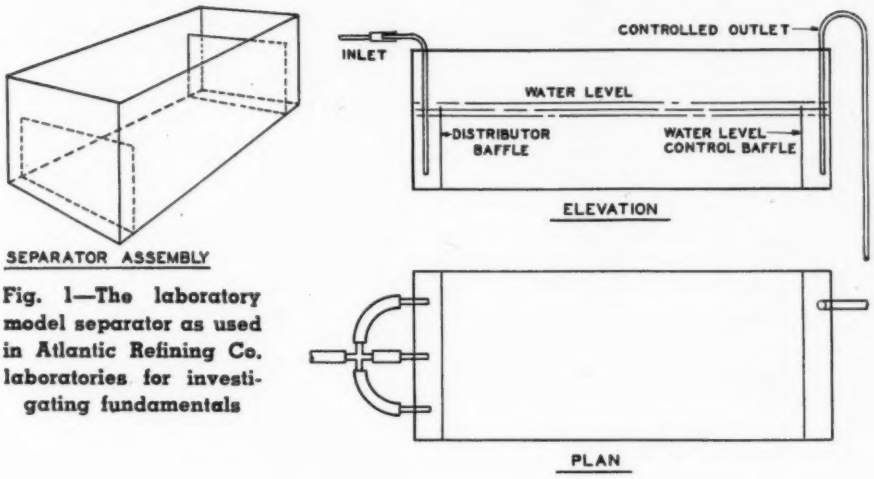



**Fig. 1—The laboratory model separator as used in Atlantic Refining Co. laboratories for investigating fundamentals**

ahead of the pipe (e.g. a matter of days), Ekman in 1910 was able to obtain laminar flow in a pipe at a Reynolds number of 50,000. This should be remembered, for it will be referred to later in discussion of design.

### Allowable Intensity Cannot Be Calculated

There is no mathematical method for predicting a degree of turbulence as an absolute value. Therefore, the Reynolds number for an allowable intensity of turbulence cannot be calculated. It must be remembered that turbulence which will interfere seriously with the rise of small globules of oil cannot be permitted. Since this level of turbulence cannot be established mathematically, experiment and observation must be employed.

This conclusion was reached early in the development of design for the equipment now commonly known as the "API Gravity-Type Oil-Water Separator." The investigation of fundamentals for the design of this equipment, and the design work also, were carried out at the Philadelphia refinery of the Atlantic Refining Co. and the model "separator" was designed, fabricated and tested on the same plant as a project sponsored by the API Committee for the Disposal of Refinery Wastes. Funds were supplied as contributions by various of the larger oil companies.

### Glass Laboratory Separator

With realization of the importance of turbulence, and of its relation to Reynolds number, a glass separator of laboratory size (12 in. wide by 30 in. long by 10 in. deep, for 6 in. flow depth) previously had been constructed for experiments with flow in sedimentation basins. It was equipped for introducing dye, so that the type of flow could be observed by the application of the coloring matter. Although this experimental set-up originally was intended for the study of flow types, it revealed other details about flow through a sedimentation basin which proved highly important.

Regardless of how carefully, or how slowly the water was introduced into the laboratory equipment, what could be regarded as laminar flow never was attained. The dye always moved in an irregular path, sometimes toward the surface and sometimes downward, or in an irregular spiral-like manner. Never did it move in a straight, horizontal path from inlet to outlet end.

The experiments with flow were carried out at approximately 70° F. (water temperature) using tap water as a supply. Ignoring the effect of dissolved solids, and assuming a temperature of 70° F. a series of flows were tried to determine where pronounced turbulence occurred, using the dye to make the water action visible. The water flow was introduced behind a distribution weir as shown in Fig. 1.

In this series of experiments, turbulence regarded as excessive occurred at a calculated velocity of 0.0086 ft./sec. At a velocity of 0.0112 ft./sec., the turbulence very definitely was excessive.

### Turbulence at Various Velocities

The next step was the investigation to determine how the degree of turbulence at various velocities would affect suspended globules of oil. For this purpose two grades of oil were employed and were introduced after being well shaken in water to produce small globules. These oils respectively were about 24° and 38° API gravity. It was found that with the 24° gravity oil the small globules were carried with the turbulence at any velocity in excess of about 0.0091 ft./sec.

Based upon the above rather crude experiments, the size and flows of an experimental or pilot plant separator were evolved using the rules of hydraulic similitude[168]. The experimental separator, because of railroad restrictions for freight movement, could not exceed 8 ft. in width, making the size ratio in relation to the laboratory separator 8:1, i.e., $n = 8$. Then:

$$V : V_m :: \sqrt{n} : 1$$

$$\text{and } R : R_m :: n : 1$$

in which $V$ and $V_m$ are velocities respectively in the experimental separator and in the laboratory separator, and $R$ and $R_m$ the hydraulic radii. Since the kinematic viscosity of the water will be the same for any given temperature, and $V$ and $R$ are the other factors in the equation for Reynolds number, the Reynolds number also will be subject to the $n$ ratio.

The indicated calculations determined the range of Reynolds numbers for the experimental separator. Flows based on these numbers then were planned. Other features of design were explored before these flows were applied, however, because a complete design for construction of the separator was necessary. But for convenience the discussion of flow will be carried to a conclusion first.

### Eddy Currents Too Pronounced

When applied to the experimental separator, the planned flows were found to cause eddy currents which obviously were too pronounced around some of the accessory equipment. A reduced series of Reynolds numbers was calculated and found to offer much more hope of effective operation. This range was from 2500 to 4000. It then became necessary to correlate these numbers with the flows permissible in a plant size separator by resorting again to the rules of similitude. To do so, however, it was necessary first to give consideration to certain practical features which have to do with width and depth. This will be discussed now so that these dimensions can be understood.

When the design for plant equipment was developed, the most satisfactory type of cleaning device was available for a basin width of only 20 ft. This width was accepted as standard for a separator unit.

Further, it was indicated earlier that in the most desirable channel cross-section the depth is one-half the width. For a width of 20 ft., the flow depth should be 10 ft. But to allow for a gravity flow to the separator from a sewer system perhaps only 4 or 5 ft. below grade, the excavation depth would be increased by perhaps 7 or 8 ft. to around 18 ft.

Many refineries are located in low areas bordering on water, so that the water-table (i.e., level of the subsurface water) is but a few feet below grade. Consequently, any excavation of considerable depth, such as the above, would require extensive shoring and dewatering, both of which are expensive. Some concession was made to such a condition, therefore, and the standard unit cross-section of flow was established as 20 ft. wide and 8 ft. deep. It should

be remembered that this is *flow* depth.

The type of flow indicated for a vertical cross section 20 ft. wide by 10 ft. deep, as determined from the range of Reynolds numbers found satisfactory in the experimental separator, was established for plant size equipment and applied to the section 20 ft. wide by 8 ft. deep.

It will be noted at once that the use of 8 ft. as the depth for a section 20 ft. wide, is a deviation from the ideal open channel section. But that this deviation is not serious can be proved for any particular installation. It can be shown that if the flow conditions have been observed, the depth in all cases will be greater than the critical at which turbulence would become excessive. This is true because the hydraulic gradient along the length of the separator is practically negligible and therefore does not cause high velocities. If desired, this depth effect can be determined from the following equation:

$$d_c = \sqrt[3]{\frac{q^2}{g}}$$

in which:

$d_c$ = The critical depth, in ft.,

$q$ = Rate of flow in cu.ft./sec./ft. width (For the section in question this value will equal the load on the separator in cu.ft./sec. divided by 20),

$g$ = Acceleration of gravity in ft./sec.$^2$.

Returning once more to the type of flow, and specifically to the Reynolds number as a measure of this factor, a range, or more precisely an upper limit of Reynolds number can be established. The original experimentation indicated that for a section 20 ft. wide and 10 ft. deep, a Reynolds number of 17,500 will not interfere with the separation of oil having a gravity of approximately 38° API.

Using the kinetic energy of the oil globule ½ ($mv^2$) as a measure of the resistance to interference, and for correlation with other gravities, for an oil of 24° API gravity, a Reynolds number of about 6000 should not be exceeded. But when applied to the section 20 ft. by 8 ft., these values will be higher. Also, for oils of a higher API gravity (i.e., lighter oils), a somewhat greater degree of turbulence is permissible.

By following the same procedure of relations it can be shown that for oils of the order of 45° API gravity, a Reynolds number of 20,000 may be used for plant design. This, however, is the upper limit. Actually, there is no lower limit to be defined by a Reynolds number, although for oils of 18° to 20° API a Reynolds number of 5000 should be used.

For oils lower in gravity, that is to say, approaching the gravity of water, the use of sedimentation as a practicable procedure for treatment of wastes to remove oil is questionable, as will be explained later. Consequently, for plant design, a curve of Reynolds numbers versus gravities such as shown in Fig. 2 can be established.

### At Variance With API Manual

This discussion of flow fundamentals and separator section has been presented in some detail for two reasons. First, it is at some variance with the recommendations of the American Petroleum Institute Manual, which is the result of committee action. Second, it not only explains the fundamentals of the basic, and probably the most important part of the design, but also establishes the capacity of the equipment.

As previously shown:

$$R = \frac{VR}{\nu}$$

$$\text{Then } R\nu = VR \text{ and } V = \frac{R\nu}{R}$$

Of the factors in the above equations, R will be known from the gravity of the oil to be separated, as applied in Fig. 2; $\nu$ will be known from the temperature and kinematic viscosity of the waste; and $R$ can be calculated from the dimensions of the standard cross section of 8 ft. by 20 ft. Thus $V$, the velocity can be calculated, and when applied to the standard cross section, the capacity of the cross section will result.

That the cross section of flow does de-

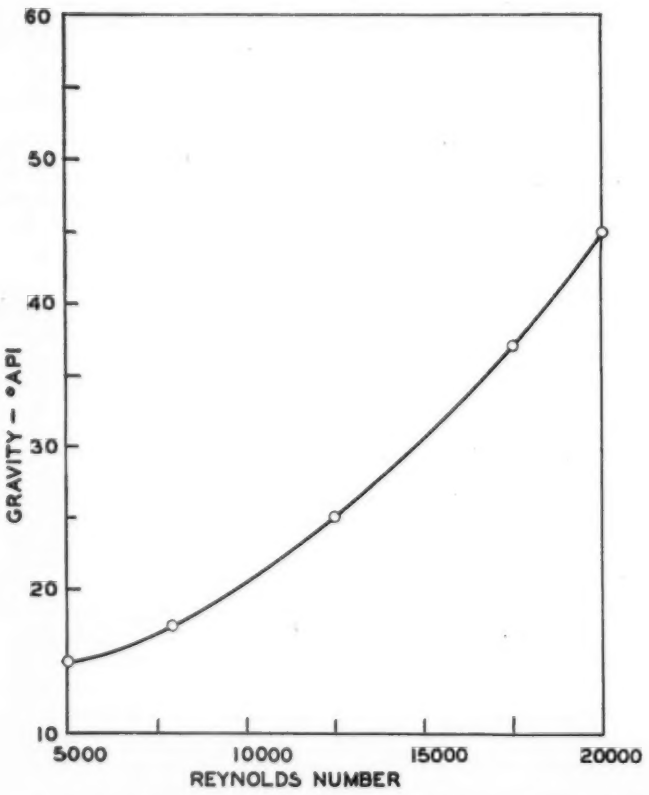



Fig. 2—Relationship of Reynolds Number to gravity (° API) of oil to be separated

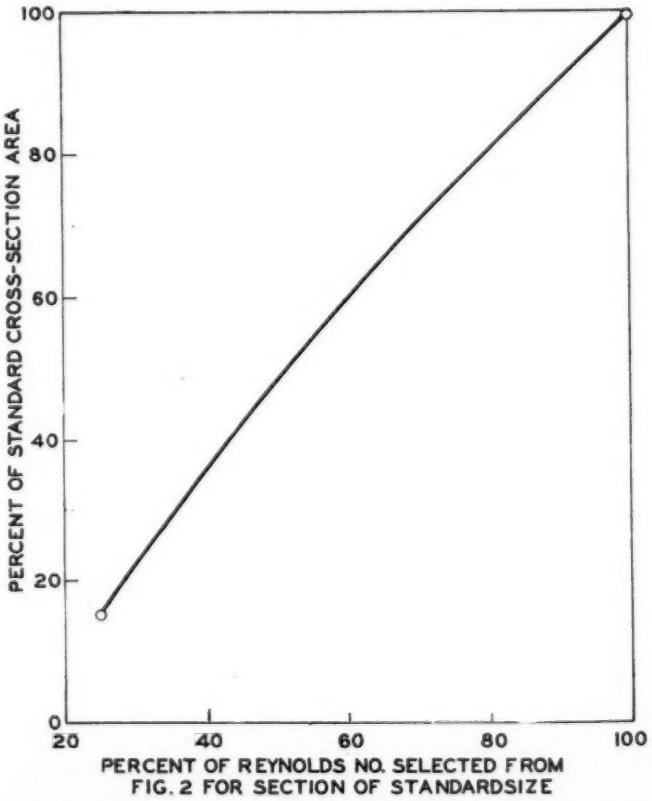



Fig. 3—Relationship of Reynolds Number to the percentage of cross-sectional area of a standard section

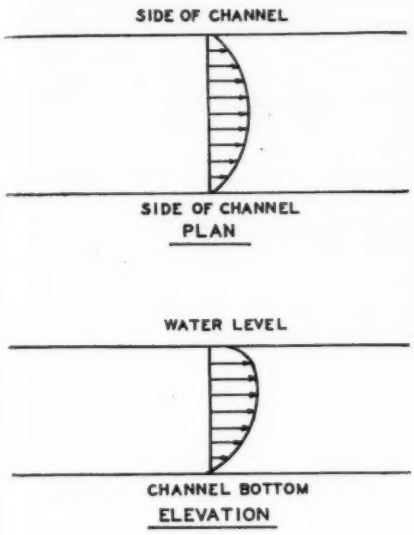



**Fig. 4—Typical relative velocity curves for open channel flow such as occurs in a gravity type oil-water separator**

termine the capacity should be emphasized, for there are many who have various ideas as to just what factors *are* involved. But it is the vertical, transverse section of flow, and the velocity of the flow of waste through this section, which determines capacity. The amount of oil present in the waste has only negligible effect on the separator capacity, but it seems that frequently this oil is regarded as the factor which controls the load the equipment can handle.

As an example, the capacity of the standard 8 ft. by 20 ft. section can be calculated. Assume that the kinematic viscosity ($\nu$) is 0.00001, and that a Reynolds number (R) of 15000 is necessary. The Hydraulic Radius ($R$) will be the section area, A, (8 x 20) of 160 sq. ft., divided by the wetted perimeter ($P$) of 36 ft. (8 + 20 + 8), which equals 4.44. Then:

$$V=\frac{R\nu}{R}=\frac{15000\times 0.00001}{4.44}$$

Simplifying the above equation the average velocity is equal to 0.0341 ft./sec or 2.046 ft./min.

Thus, a section area of 160 sq. ft. will carry 160 x 2.046 or 327 cfm.

This calculation of capacity for the standard section is basic to separator design. It will be referred to shortly when design procedure is summarized. At this point the basic procedure for design when the load is greater or less than that of a standard section, will be considered. The two procedures can be explained at the same time.

Assume that with a given set of conditions, i.e., Reynolds number and kinematic viscosity of water, the standard section will carry 350 cfm. but the waste flow to be subjected to sedimentation is 450 cfm. Obviously, a single standard section will not be large enough, yet two such sections will be larger than necessary. The solution of this situation is the building of two parallel sections, each with a capacity of half the 450 cu. ft. or 225 cu. ft.

This procedure should be followed in all cases where the waste quantity exceeds the capacity of the standard section, unless the economics of design and construction indicate that several standard sections in parallel should be used even though they provide some excess capacity.

Returning to the example above, the Reynolds number will be lower as a result of the smaller size. The velocity also will be lower as will the cross-section. The kinematic viscosity of the flow will remain the same.

Using the dimensional interpretation of rate of flow as

$$\sqrt[2.5]{Q},$$

and of area of cross-sections as

$$\sqrt{A}, \quad (168)$$

the area of the smaller equipment can be obtained from the equation:

$$\sqrt[2.5]{Q} : \sqrt[2.5]{Q_m} :: \sqrt{A} : \sqrt{A_m}$$

$$\text{Then: } \sqrt[2.5]{350} : \sqrt[2.5]{225} :: \sqrt{160} : \sqrt{A_m}$$

From this relationship the area of the smaller equipment is 112.5 sq. ft.

This area of cross-section is the product of the breadth ($b$) and the depth of flow ($d$), and $b = 2.5\ d$. Then:

$$A = b \times d = 2.5d^2$$

By solving for $d$, the value is 6.7 ft. and $b = 16.75$ ft. From these dimensions the Reynolds number can be calculated.

$$V=0.033 \quad ft./sec.; \quad R=3.72:$$

$$R=\frac{0.033\times 3.72}{.00001}=12276$$

By this procedure, equipment smaller than the standard cross-section can be calculated. Equipment for very small flows will be discussed when the design procedure is summarized.

### Correlate Reynolds Number to Size

As a matter of convenience, for equipment which is to be designed for capacity less than that of the standard section, but not so small as those just mentioned for special consideration, a curve of Reynolds number relationships as correlated with size of equipment is shown. To use this curve, the proper Reynolds number for the standard section is selected from Fig. 2. Then the percentage of the standard cross-section which is represented by the area required by the flow to be treated, can be applied in Fig. 3, and the Reynolds number for the separator size found. This will serve as an approximate check on calculations of the Reynolds number when the equipment size is calculated.

It will be of little use to decide upon flow character and equipment size unless every effort is made in detail of design to protect the flow; to see that the character is maintained as completely as possible. Perfect distribution of flow, in which the velocity at any point in a transverse vertical plane is the same as that at any other point in the same or any other similar plane, cannot be attained for several reasons.

In the first place, as a part of design the Reynolds number is too high. Secondly, the fluid flowing is viscous, and will be retarded by walls and accessory equipment because of friction. Thirdly, the movement of particles either upward or downward causes disturbances. Fourthly, the flow cannot be introduced into the equipment in a manner which is conducive to perfect distribution and is at the same time practicable.

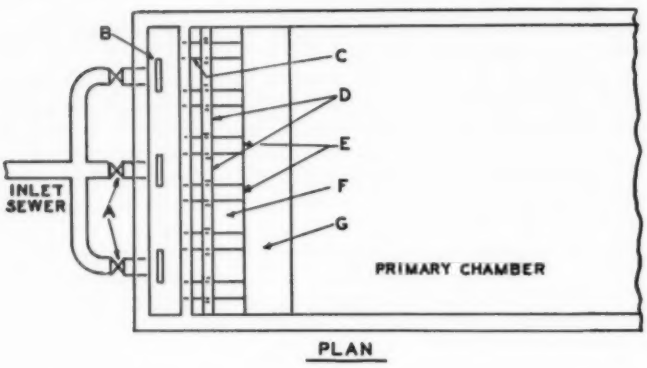
### Choice of Design for Open Channels

There is a choice of design in open channels. Either the channel can be made long enough, so that in its lower reaches the type of flow desired, and corresponding to the Reynolds number selected, will eventualize, or the flow can be "stilled" as much as possible before introduction into the equipment to bring about the desired type of flow quickly. The first procedure, obviously, is impracticable, or at least uneconomical. Therefore the second procedure must be followed.

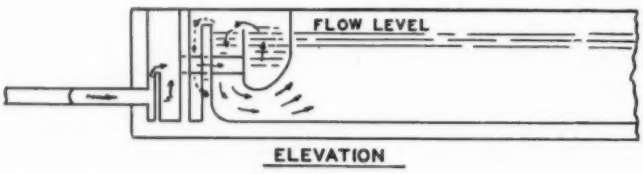
It will assist understanding of open channel flow to have full realization of the variations in velocity. Unlike the conditions existing when liquid flows in a pipe where the pressure is equal on all sides, in an open channel the pressure above is atmospheric, and the velocity varies with flow depth on the sides and bottom. Also, there is boundary on all sides in a pipe, while there is boundary on only three sides of a channel. Consequently, the flow when turbulence is not excessive follows the general pattern shown in Fig. 4. It shows clearly that the velocity varies with the depth, and that there is retardation along the walls and bottom.

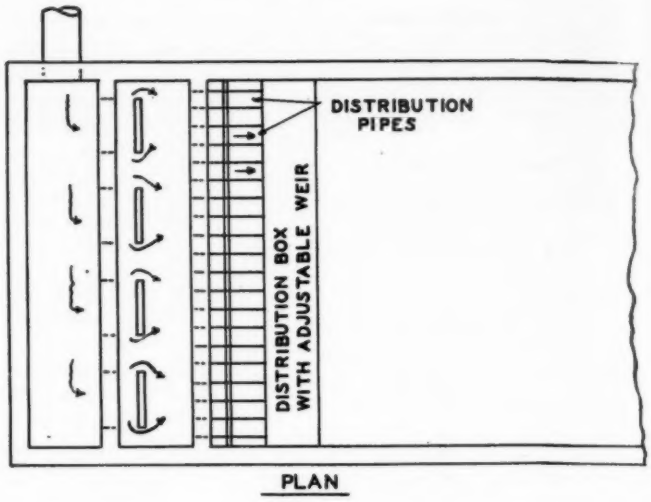
The shape of the velocity curve will vary with the quantity of liquid flowing through the channel. The velocity of flow will vary with the slope of the channel. Control of velocity by use of Reynolds number as a convenient measure of turbulence will prevent excessive velocity and therefore excessive loading. The slope of the chanel bottom for such sedimentation equipment as that in question can be ignored.

By use of the equation for critical depth it will be apparent that the flow depth is such that practically the entire body of liquid in the separator will flow forward in a tranquil manner, because the critical depth would occur only a few inches above the bottom. It is into this zone of low turbulence that the discharge from the sewer or ditch leading to the separa-




A = DISTRIBUTION CONTROL GATES TO BE USED IF NECESSARY
B = VELOCITY HEAD BREAKER BAFFLES
C = OVERFLOW SLOT IN CASE FILM-RUPTURE BECOMES PLUGGED
D = ARCHWAY COMMUNICATION BETWEEN OVERFLOW SLOT AND PRIMARY CHAMBER
E = INLET PIPES
F = FILM RUPTURE CHAMBER PERFORATED PLATE NOT SHOWN
G = DISTRIBUTION BOX AND ADJUSTABLE WEIR



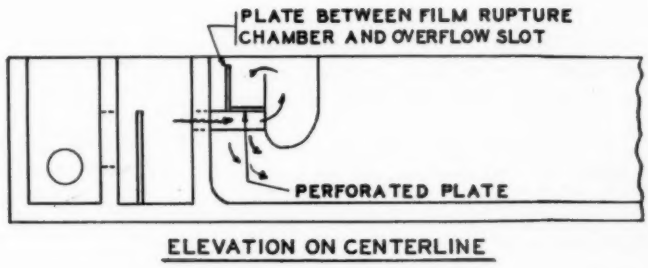




**Fig. 5 (Left)—Typical design of front inlet end of a separator for optimum distribution. (Full line arrows show normal path of flow; dotted arrows path of overflow of film rupture chamber). Fig. 6 (Right)—Another type of distribution equipment for inlet end of separator**

tor is to be introduced in an evenly distributed manner.

### "Stilling" Minimizes Turbulence

A study of Reynolds original experiments, and of the experiments of others[144], will show that one of the major factors which will contribute to minimizing turbulence is "stilling" ahead of introduction into the channel. This can be accomplished either by means of a relatively large stilling basin ahead of the channel, from which the flow can be introduced properly, or by gradually stilling in steps. Except in special cases the latter is the most economical, and its application offers other advantages.

The flow leaving the sewer is under both gravity head and velocity head. The former must be accepted, but the latter, since it contributes to jet action, must be eliminated. Much of this elimination can be attained as a first step by dividing the flow and then impinging each stream against a baffle. In this way the energy will be dissipated in eddy currents. The mechanics of this dissipation are not too critical. Methods are illustrated in Fig. 5 and 6. Others can be devised.

The eddy currents then must be "stilled" out of the forward flow. This again is accomplished by further dividing the flow and then introducing it into a stilling basin. The stilling basin is critical in its operation. It must provide a head and capacity which will slow down and smooth out as much of the remaining turbulence as reasonably is possible, because from this basin the flow is introduced into the sedimentation chamber proper by spilling over a sharp edged weir. The stilling basin should be level and the weir crest should be adjustable so that it can be reset as found necessary when checked frequently. This is of paramount importance.

The general arrangement of the distribution equipment is shown in Fig. 7, together with dimensions which will relate the size of the stilling basin, or distribution box, to the size of any particular separator through the separator depth.

Fig. 7 illustrates another feature which can be used with this design. The space between the distribution box and the front wall is used to cause rupture of films which confine oil and water in water-in-oil emulsions such as those which occur in tank bottoms.

### Use Raschig Rings or Cinders

To accomplish this end the space is partly filled with Raschig rings of about 2½ in. diameter. These are supported on a perforated plate laid across the pipes leading to the distribution box. Hard cinder of the same general size as the Raschig rings and which will support the weight of its own superimposed load also has been used, and in some instances has been found to be superior to the Raschig rings.

The space, which then becomes known as the "film rupture chamber" should be loaded only to a depth which will serve the purpose indicated by the name. The perforated metal plate must be level, and the total area of the perforations should not exceed by more than about 33 1/3% the sum of the cross-sections of the inlet pipes on which it rests.

This space serves still another purpose. In equipment functioning properly, and not overloaded, a layer of oil will accumulate in the space. This oil gradually should fill the entire chamber so that all flow must pass through it. The idea is to promote coalescence, i.e., have all small globules merge to form large globules or masses which will rise much more rapidly. Such action promotes effectiveness in removal of oil from the waste flow.

There has been complaint that when the space designated as the film rupture chamber is filled, or even partly filled with Raschig rings or similar materials the space becomes blocked. Investigations of such blockage have revealed that often this is due to algal growths, or to sanitary sewage, or at times to floating masses of coke. None of these materials ever should be allowed to enter the separator at any time, for it will so seriously interfere with the functioning of the equipment that the

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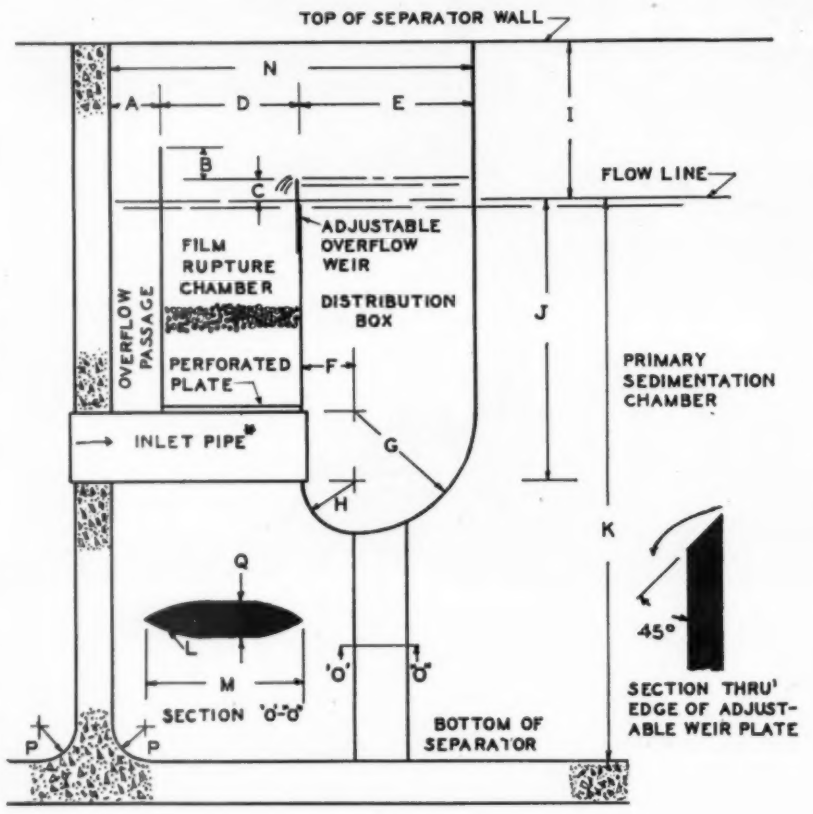
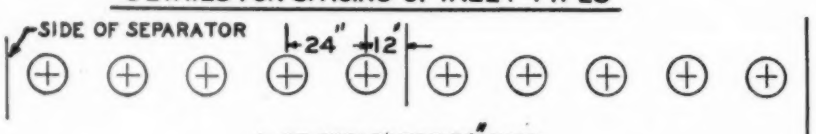



LEGEND:

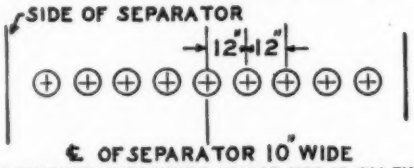
A = 0.1 K
B = 4 in. IN SMALL SEPARATORS
6 in. IN LARGE SEPARATORS
C = 1 to 6 in. RANGE FROM SMALL TO LARGE SEPARATORS
D = 0.25 K
E = 0.15 K + I. D. INLET PIPE
F = 0.075 K
G = 0.075 K + I. D. OF INLET PIPE RADIUS
H = 0.075 K = RADIUS
I = DEPENDS UPON HEIGHT OF END AND SIDE WALLS UPON FLOW LINE
J = 0.5 K
K = DEPTH OF FLOW
L = 4 in. = RADIUS
M = 0.075 K
N = 0.5K + I. D. OF INLET PIPE
P = 0.075 K = RADIUS
NOTE: Not Drawn to Scale

*DETAILS FOR SPACING OF INLET PIPES




℄ OF SEPARATOR 20" WIDE

TYPICAL ARRANGEMENT OF INLET PIPES WHEN NONE IS ON CENTER LINE OF SEPARATOR




℄ OF SEPARATOR 10" WIDE

TYPICAL ARRANGEMENT OF INLET PIPES WHEN MIDDLE PIPE IS ON THE CENTER LINE OF THE SEPARATOR

NUMBER, SIZE, AND SPACING OF INLET PIPES

| Width of Separator, Ft. | Number of Inlet Pipes | Size of Inlet Pipes, In | Spacing of Center Line of Pipes, in. | Pipe on Center Line of Separator | Distance of Pipe From Center Line of Separator If Not on Center Line |
|---|---|---|---|---|---|
| 20 | 10 | 12 | 24 | NO | 12 |
| 18 | 10 | 10 | 21 | NO | 10½ |
| 16 | 10 | 10 | 18 | NO | 9 |
| 14 | 9 | 10 | 18 | YES | 0 |
| 12 | 9 | 10 | 15 | YES | 0 |
| 10 | 9 | 8 | 12 | YES | 0 |
| 8 | 7 | 8 | 12 | YES | 0 |

**Fig. 7—Diagram of distributor design with principal dimensions. All dimensions are based upon the depth of flow**

waste treatment will be subject to justifiable criticism. Just why this will occur will be explained when the limitations of sedimentation as a treatment process are discussed.

The distribution functioning of the inlet end of the separator as presented in Fig. 7 now can be summarized. The reservoir effect previously mentioned will be apparent in both the distribution box and film rupture chamber. An important feature of this design is the complete loop or reversal of flow which it brings about. Actually this is a double reversal, in the first half of which there is almost complete stoppage of the waste movement by the head against it in the distribution box, thereby breaking down the velocity head at the entrance pipes.

The well stilled waste then is even more completely distributed by the action of the carefully levelled distribution weir. This has another very important effect, in that it brings the waste flow into a relatively thin layer as it passes over the weir, permitting a levelling of any great temperature and gravity differences which might bring about thermal currents or stratification in the sedimentation basin which follows.

This temperature levelling effect is carried on even further in the film rupture chamber where the rupturing agent, as well as the mass of liquid in the chamber, tends to assume a relatively constant temperature which resists change. This produces the averaging effect.

Finally, the distribution is further aided by the perforated plate which forms the bottom of the film rupture chamber. The perforations in total area purposely are made only enough larger than the total area of the inlet pipes to permit all flow to pass, but with some loss of head so that good distribution is assured. This has the effect of correcting channeling which might occur. From this plate the flow enters the sedimentation chamber proper.

In making this entrance the flow passes a throat area which gradually opens out without angle or other disturbing feature. This mode of entrance provides the smoothest inlet conditions which can be devised, and such conditions are paramount to effective treatment. The actual sedimentation starts as soon as the sedimentation chamber is entered. The design of this chamber, and other features of the separator, will be described in the next article.

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# Production of Synthetic Lubricating Oils By the Voltolization Processes

By GEORGE G. PRITZKER
Shell Development Co., San Francisco

**The voltolization processes for producing synthetic lubricants consist of subjecting an oil, or mixture of oils, to a silent electrical discharge. Improved lubrication properties, including increased viscosity index, are said to be imparted to the original oil. The name "voltolization" is not common in the English literature, but is apparently derived from the German lubricant "Voltol" produced by such an operation.**

**Although such processes have been known for over 40 years, little attention has been paid to them in this country. With the interest now being shown in synthetic lubricants, however, voltolization should attract greater scrutiny. Mr. Pritzker's accompanying survey of the literature on the subject will prove helpful to anyone undertaking such an investigation.**

IT IS surprising that little mention, if any, is made of the production of lubricants by the voltolization process in Germany, Japan, or in the Allied countries during the second World War. This process for manufacturing lubricants was developed commercially by De Hemptinne around 1912. At the outbreak of World War I, the De Hemptinne oil plant in Belgium was seized by the Germans and exploited throughout the war.

Essentially, the De Hemptinne process[1] for producing lubricating oils by voltolization comprised charging a blend of from 15 to 50% fatty oil and mineral oil into a horizontal cylindrical drum with scoops around the inside periphery. The drum rotated about a horizontal axis, and the scoops caused the oil to drip continuously over the electrodes in the center of the apparatus.

This process was later improved by the Continental Caontchouc and Gutta Percha Co.[2] by the introduction of catalytic agents during the voltolization process in order to produce improved lubricants.

### Transferred to Germany in 1917-18

In 1917-1918, under the leadership of Dr. Nernst, Germany transferred most of the equipment from the De Hemptinne plant in Belgium and erected at Potschapple a plant called the Deutsche Elektrion Ol Gesellschaft, which in the last year of the war produced about 1650 tons of aviation oil[3] for Germany. The Potschapple voltolization process comprises charging oil into a horizontal cylindrical steel vessel under reduced pressure. No hydrogen or other gas was introduced into the vessel and the oil was held at 80° C. in order partially to vaporize it. The electrode elements were made up of aluminum plates. Scoops were attached to the electrode carrier, by means of which the oil was picked up and poured between the plates of the electrodes during the electric discharge and was thus subjected to the action of the high tension electric current. The time required for the operation varies with the type of oil treated.

In vertical voltolizers, which were developed later, the oil is fed at the top of the vessel, and a current of nitrogen or some other gas is introduced at the bottom so as to agitate the oil constantly, causing better contact between the oil and the glow-discharge.

### First Discovery Was in 1874

Although De Hemptinne was the first to produce lubricants on a commercial scale by the voltolization process, he was not the first to observe that subjecting oils or various hydrocarbons to electric discharges results in the production of oils having lubricating properties. De Wilde[4] in 1874 first reported that a yellow oil can be produced by condensing acetylene in an ozonizer. Later, Losanitsch and Jovitschitsch[5] subjected ethylene to silent electrical discharges and produced thick yellow oils boiling between 200-260° C. and believed to have the general formula $C_{12}H_{22}$. In 1905, Collie[6] reported that by subjecting ethylene to voltolization, a mixture of hydrocarbons boiling from 60° C. upwards can be produced. Continuing work along these lines, Demjanov and Prianischinkov[7] subjected ethylene to silent discharge of 12000-13000 volts in order to produce a lubricating oil.

The voltolization of organic materials can be accomplished by electric sparks, arc, silent discharges, ultra violet rays, etc. According to Nernst and De Hemptinne,[8] oils subjected to electrical charges split into positive and negative ions and these ions travel toward the corresponding electrodes similar in manner to the ordinary dissociation of inorganic compounds. Thus, ionization of hydrocarbons occurs which causes a splitting into hydrogen and unsaturated hydrocarbons to take place. This is followed by electronic bombardment of the hydrocarbon atoms, which causes a cracking reaction to take place. The residues then polymerize to molecular complex of considerable size which result in the improved oil products.

### Several Factors Involved

Many variable factors are involved when subjecting materials to electrical pyrolysis. The type of material treated, the type and intensity of electrical energy used, the kind of electrodes employed, the temperature and pressure of the reaction—all play a vital part in producing the final end product.

When a hydrocarbon is subjected to the action of silent electrical discharges, the weakening of the hydrocarbon chain depends upon the strength or voltage of the discharge. With aromatic and naphthenic type oils, more electrical energy is required than when using paraffinic oils. Temperature is an important factor in the voltolization process, and it has been observed that the higher the temperature, the better the reaction.

De Hemptinne[9] produced lubricating oils by hydrogenation of unsaturated compounds under the influence of silent electric discharge. The apparatus used consisted of a suitable vessel having a series of revolving metallic discs partly immersed into material such as mineral oils and their mixtures, which are hydrogenated, and the discs intermittently connected to the poles of high tension alternating current. De Hemptinne in a British patent[10] also disclosed that it is not necessary to use mixtures of vegetable and mineral oils to produce lubri-

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cants by the voltolization process, and that by adding to a fresh mineral oil a small amount of polymerized oil produced by exposing an oil to an electric discharge under reduced pressure until the oil has attained a desired viscosity, the entire oil mixture is polymerized rapidly and a lubricant of desired viscosity is produced. The process is repeated with a charge of fresh mineral oil.

### Ossay Oils Were a Modification

The famous "Ossay"[11] lubricating oils produced by the Oil Works Stern-Sonneborn in Germany during the first World War were a modification of this process. To produce Ossay oils, a small amount of pure mineral oil was voltolized until a gelatinizing point was reached. A certain amount of this oil was removed and a fresh mineral oil added and also voltolized to a gelatinizing point.

In order to improve the quality of lubricating oils, Ellis[12] treated the oil with ultra-violet light to remove fluorescence or bloom. The gumming agents present in the oil also appear to be polymerized, forming saturated and unsaturated bodies which become useful lubricants.

A "Voltol" lubricating oil[13] can be produced by hydrogenating the unsaturated constituents of mineral oils under a pressure of 0.9 atm. The unsaturated constituents are produced by subjecting the oil to silent electric discharges of 4300 to 4600 volts and 19 to 23 amperes. Another "Voltol" lubricating oil was prepared from kerosene[14] by subjecting it to an alternating current of 4500 volts in horizontal vessels. A pressure of 60 cm. mercury is maintained in the vessel and hydrogen is passed through the oil mixture until a lubricating oil of a desired viscosity is attained.

### Use of Hydrogen Cuts Costs

Generally, voltolization of pure hydrocarbons to produce lubricants has proved uneconomical because the process is too slow. However, with the discovery that by the introduction of hydrogen during the voltolization treatment of hydrocarbons, lubricating oils can be produced economically, Voltol oils came into their own. Lubricating oils can be produced by introducing hydrogen to turpentine oil, coal-tar benzol, and other unsaturated oils during voltolization. Still another way of producing Voltol oil[15] is by treating mineral oil with high tension electric current at 60-80° C.

Eichwald[16] produced lubricating oil from low temperature tar by removing the paraffin and phenol from the tar and subjecting the distillate to an electric discharge. Eichwald[17] also produced lubricating oils by subjecting mineral oil to the action of an alternating current. According to Eichwald, during this process hydrogen is caused to split off and combine with the unsaturated constituents of the hydrocarbons. This produces a building up or polymerization of the product into the desired lubricant. Eichwald[18] later discovered that lubricating oils could be produced by voltolizing crude low temperature tars obtained from large lignite deposits in Germany. He also found that no voltolizing glycerides of fatty acids, the glyceride portion of the molecule was unaffected and the resultant product proved to have good lubricating properties.

### Mercury Vapor Rays Aid Process

Goldstein[19] disclosed that by subjecting petroleum hydrocarbon to the action of light of short wave length, such as is obtained by the use of a mercury vapor lamp, polymerization occurs and a lubricant is produced. A French patent[20] discloses that by subjecting hydrocarbon gases to the action of a high tension electric field in the presence of a tin catalyst and at pressures above 1 atm., a good lubricant is produced.

Lubricating oils were also obtained from coal tars,[21] mineral oil, or other carbonaceous materials, extracting or destructively hydrogenating the solid materials, or cracking or destructively hydrogenating the liquid, and exposing the liquid produced, or its fractions, to the action of high tension, high frequency electric current. Epner[22] obtained lubricating oils by subjecting methane gases, gases containing methane, gases obtained in cracking hydrocarbons, or ethane or ethylene from coke-oven gases to the action of alternating electric field and high frequency and voltage and then hydrogenating the product.

### Use High Voltage and Vacuum

Wolf[23] disclosed that lubricating oils can be produced by subjecting mineral oils to a glowing electrical discharge, alternating current at 5000 volts, 80° C., and at a vacuum pressure of 60-70 mm.

Rabek[24] in an article describes a Polish continuous process of producing lubricating oil by subjecting a blend of mineral oil and vegetable oil to a high frequency electric current.

By subjecting mineral oil to high tension electric alternating currents of frequencies between 500 and 1000 cycles[25] under an absolute pressure of 0.01 atm., the viscosity of an oil can be increased and a good lubricating oil product thus secured. Siemens and Hahske[26] produced lubricants by voltolizing mineral oils in the presence of air rather than in inert atmospheres with a high frequency alternating current of 1000 cycles per second. By condensing butane gas by electrical means, Lind and Glockler[27] produced liquid fractions of viscous oil.

Taylor[28] polymerized ethylene in a quartz vessel containing mercury vapor in the presence of liquid mercury, and the system was thereafter exposed to the light of a cooled mercury arc to produce a heavy oily material.

Viscous oils having good lubricating properties were obtained by subjecting alkylated naphthalenes[29] to the action of silent electric discharges. The lubricant was produced by passing alkylated naphthalene through an ozonizer under reduced pressures and passing an alternating electric current through the liquid.

### Find Olefins Can Be Converted

Volmar and Hirtz[30] observed that when olefins are subjected to silent electric discharges and the product then hydrogenated, saturated hydrocarbons of ten carbon atoms are formed. This saturated material had good lubricating properties. It has been observed also that amylene[31] vapors, when mixed with hydrogen and treated with an electric discharge in an ozonizer are converted into liquid saturated hydrocarbons of the type $C_5H_{12}$.

Lubricating oils which are oxidation resistant and which have little tendency to deposit carbon in an engine were produced by the "Elekton"[32] process which comprised subjecting oils to electrical discharges under very high tension.

An interesting review article on elec-

### WHAT VOLTOLIZATION DOES

In response to a request from the editors of Petroleum Processing for further information on the nature of voltolization processes and how they work, Mr. Pritzker wrote as follows:

"The action of glow-discharges on oil is not fully understood. However, it is known that through voltolizing oils attain increased lubricating properties. When vegetable and animal oils are voltolized they lose their characteristic odor and increase in viscosity.

"It is believed that by this process the unsaturated molecules are acted upon and polymerization takes place. Thus, low molecular weight olefins can be converted to high molecular weight hydrocarbons in the lubricating range. These materials can be further treated by introducing polor bodies so as to increase the lubricity of the product, or can be reacted with sulfur and the like to impart extreme pressure properties.

"Voltolization also aids in hydrogenation of unsaturated compounds and gives greater control to the process."

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trical treatment of oils is presented by Nash et al.[33] in which the work of Berthelot on electrical treatment of propylene is discussed, as well as the methods of Demjanow and Prianishnikov in obtaining an oil from electrical treatment of ethylene. The electronic bombardment theory of Eichwald also is discussed, as well as the disclosure that lubricating oils can be produced by treating alkylated naphthalenes or halogenated paraffins with silent electric discharges. Mention also is made of the fact that voltolizing materials in the presence of powdered coal reduces the voltolization time.

### High Frequency Currents Used

Pier[34] discloses the production of lubricating oils from coal, tar, mineral oil, etc., by converting the material to a liquid phase and treating the liquid with high frequency electric currents, preferably high tension currents. The treatment is carried out in the presence of finely divided carbonaceous materials; the voltage used varies from 2000-12000 volts.

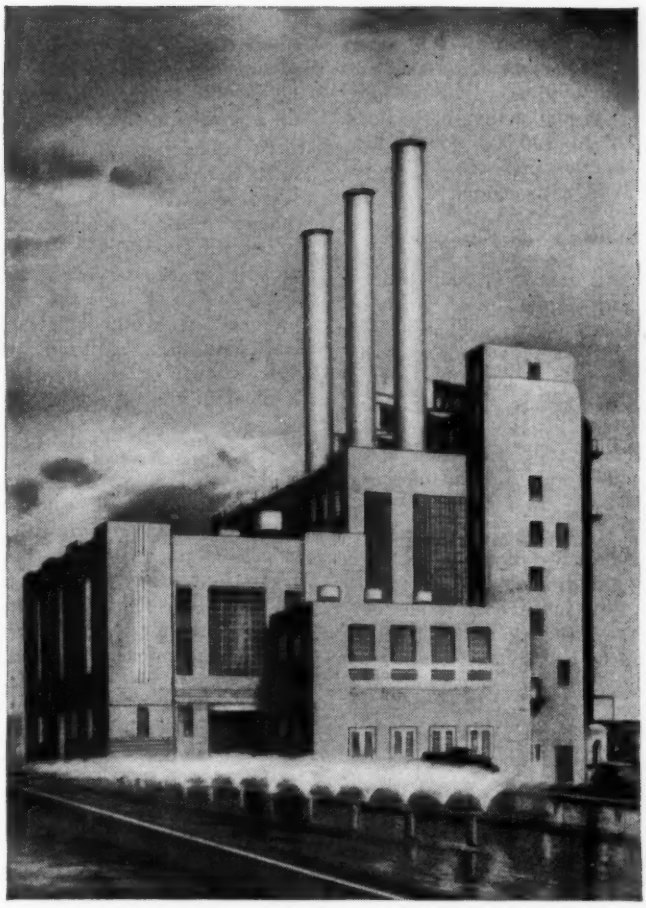
Petrov and Bogoslovskaya[35] studied the effect of silent electric discharges on various hydrocrabons, such as cracked and straight run kerosene, octylene, hexadiene, dodecane, decalin, cumene, and alkylated naphthalene. Their conclusion was that some of the materials which result from such treatment possess good lubricating properties. Tarasov[36] studied the effect of electric discharges on cracked kerosene in a Siemens ozonizer when electric current was varied.

Tanneberger[37] produced lubricating oils by subjecting methane to an electric arc treatment and compressing the material to 10 atm. and removing the water as it was formed during the reaction. Henry[38] produced lubrication oils by vaporizing hydrocarbons in a field generated by electric light ray and electric wave coils in the presence of nickel and other metallic catalysts.

### Oils from Paraffin Waxes

Lubricating oils can also be produced by subjecting paraffin wax hydrocarbons[39] having a molecular weight of 330 to 350 to treatment with a silent high frequency electric discharge. In order to produce a lubricant, Woods[40] subjected blends of crude scale wax and waxy Mid-Continent overhead oil to the action of silent electric discharges under reduced pressure.

To produce hydrocarbon oils, Michot-Dupont[41] heated coal or similar solid combustible materials to 500° C. to drive off the volatile ingredients. The temperature was then raised to 900° C. to produce a semi-coke, and the gases produced, such as hydrogen, methane, carbon monoxide, carbon dioxide, and benzol, toluene, xylene, etc., were conducted to a suitable vessel. The coke was treated with steam to produce water-



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gas and conducted to a gas vessel. Hydrogen was introduced into the vessel at atmospheric pressure and temperature of from room to 600° C. This material was subjected to the action of a static field of 80,000 to 100,000 volts, ultraviolet light in the presence of nickel and tin admixed with mercury.

### Study Influence of Electrodes

An interesting article on voltolization of kerosene and various other hydrocarbons is that of Margolina, et al.[42] The influence of gas such as hydrogen, nitrogen, and air is discussed, as well as the influence of various electrodes such as aluminum, iron, and glass, and the effect of the tension and frequency of the current upon the properties of the final product.

Wiezevich[43] produced synthetic lubricants by voltolizing diphenyl or other aromatic compounds by subjecting them to the action of silent electric discharges. To improve the viscosity of these products, polymers of isobutylene, hydrogenated poly-vinyl acetylene, polychlorprene, poly-vinyl esters, resins, such as glyptals, bakelite resins, petroleum resins, thickened glycerides, poly-axhydrides, and their esters, lactones and lactides were added. Wiezevich[44] also produced synthetic lubricating oils by heat treating or subjecting to silent electric discharges organic esters and then hydrogenating them in the presence of catalysts or halogenating the product and adding sulfur to it. The esters which were thus treated were dibutyl phthalate, tricresyl phosphate, ethyl dibenzyl malonate, butyl acetyl ricinoleate, ethyl linoleate, methyl cyclohexanol stearate, benzyl benzoate, etc.

By subjecting a waxy petroleum lubricating oil to ultra violet light, such as from a mercury vapor lamp, Liberthson[45] produced low pour point oils.

### Employ Friedel-Crafts Catalyst

Pier[46] produced synthetic lubricating oil by polymerizing in the presence of a Friedel-Craft catalyst such as aluminum chloride, zinc chloride, ferric chloride, and substances which prevent or hinder oxidation, such as elemental sulfur, amino compounds, organic oxygen compounds of mineral oil, tars, their distillation products, or cracked or destructive hydrogenation products of coal. He used also hydrocarbons of high molecular weight rich in hydrogen, such as hard and soft wax, crude paraffin wax, ceresine, ozokerite, petroleum jelly, or highly viscous lubricating oil, or crude lubricating oil or alcohols of high molecular weight, such as cerylalcohol, organic acids of high molecular weight, as, for instance, cerotic acid or esters of high molecular weight, montan wax, beeswax, or glycerides of such fatty acid as stearic, palmitic, and oleic acids, such as fats or train oils, which can be polymerized to produce lubricating oil. Gaseous olefins, such as ethylene and isobutylene, may also be condensed to lubricating oils. These materials can be voltolized, e. g., by treatment with silent electric discharges of high voltage and high frequency, to produce synthetic lubricating oil.

By subjecting mixtures of carbon monoxide and hydrogen[47] to the action of silent electric discharges at high frequency, lubricating oils can be produced. Lubricating oils can also be produced by voltolizing paraffinic and nonparaffinic components of mineral oil[48] in the presence of synthetic glycerides or by admixing the voltolized product with rapeseed oil or the like, or voltolizing a blend of the materials.

### Improve Synthetic Oils

Tilton[49] improved the properties of synthetic lubricating oil by subjecting the oils to silent electric discharges. The process was conducted in a Siemens ozonization tube or in a Trommel type voltolizer in which a thin film of oil was continuously passed between electrodes in a reaction chamber maintained under an absolute pressure of about 2-10 or 20 cm. of mercury with an electric potential of about 1000 to 10,000 volts or more at a frequency of about 500 to 10,000 cycles per second. It is known that the lubricating properties of nonparaffinic oils boiling at about 400° F. can be improved by treating them with silent electric discharges.

Clemens[50] produced lubricating oils by voltolizing solid and liquid oily materials, such as refined mineral oil, using a direct current at a temperature ranging from −100 to +450° F. Matheson[51] produced lubricants by subjecting oils and waxes to the action of silent electric discharges using metal electrodes coated with solid organic dielectric materials in order to prevent any contact of the materials treated with the electrodes.

Ellchwald[52] produced lubricating oils by treating polyesters of unsaturated aliphatic acids and mono or dihydric alcohols either saturated or unsaturated in admixture with semi-drying or poorly drying or non-drying fatty oils with boron flouride or by electrical voltolization.

### Mix Hydrocarbons With Fats

Pier,[53] by subjecting paraffin waxes, petrolatum, or by mixing these hydrocarbons with fats, fatty oils, alcohols, esters, and acids such as stearic, palmitic, or oleic, and condensing these materials by means of silent electric discharges, produced lubricating oil. By wax Pier meant materials of wax origin obtained from mineral oil or brown coal and solid isoparaffins such as Palembany wax or dehydrogenated paraffin waxes.

Franceway[54] produced low pour point lubricating oil by polymerizing straight chain hydrocarbons of 10 or 12 carbon atoms or more, or alcohols, esters, ethers, acids, and ketones containing at least 10 carbons, by applying high tension electric discharges to the material. The process is carried out under reduced pressure and high voltages of 10,000 to 15,000.

By subjecting olefins to the voltolization process, Rosen[55] produced lubricating oil. The initial material was deyhdrogenated by chemical action and then polymerized by voltolization. For example, petrolatum and paraffin wax were rendered unsaturated by chlorination and dechlorination or dehydrogenation by heating in the presence of catalysts such as alumina, active clay, etc. The material was voltolized by the action of high tension silent electric discharges. The heat liberated in the reaction zone was between 100-300° C., and the process can be carried out in the presence of hydrogen, carbon monoxide, carbon dioxide, oxygen, air, or in the presence of sulfur, halogen, $H_2S$, phosphorus, boron fluoride, ketones, etc.

### Produce Oxidation Resistant Oils

Sweeney[56] produced oxidation resistant lubricating oil having high viscosity and VI by segregating and hydrogenating materials secured from solvent extraction agents having a preferential selectivity for compounds having a low ratio of hydrogen to carbon, and voltolizing the hydrogenated material.

Schick disclosed[57] that synthetic lubricating oils produced by the Fischer Process can be improved by subjecting the oil to an electric field and separating the precipitate formed from the oil.

Pier[58] produced lubricating oil from initial materials containing 13.5 to 15 parts of hydrogen for each 100 parts of carbon; these materials should have a mean molecular weight of at least 170. Examples of such materials are saturated and unsaturated liquid, semi-solid, or solid paraffinic hydrocarbons of high molecular weight (250) rich in hydrogen, and boiling above 250° C.; they may come from any origin, such as by the low temperature carbonization of brown coal or shales or by destructive hydrogenation of coals, tars, mineral oil, etc., or prepared by reduction of oxides of carbon with or without the aid of elemental phosphorus or by condensation of constituents of gases obtained from cracking or low temperature carbonization processes or mixtures of the said initial materials. By treating hydrocarbons of low molecular weight with high frequency electrical currents, lubricants can also be produced.

### Mix Waxes and Fats

By subjecting paraffin wax and similar waxes or their mixtures with fats, fatty oils, high molecular weight alcohols, esters, acids, to the action of silent electric discharges, Pier[59] produced lubricating oil. For example, ceresine was treated by Pier at 80-100° C. in a Siemens ozonization tube at a pressure of 5-10 mm. (Hg. gauge) with electric discharges at about 7,000 to 10,000 cycles from 25 to

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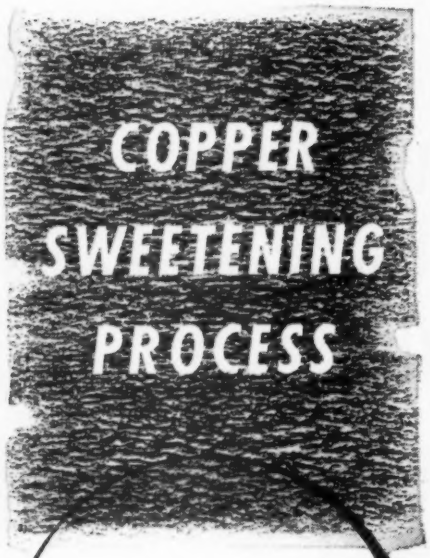


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30 hrs. After 20 to 22 hrs., hard paraffin wax was added as a dilutent. The resulting mixture was subjected to vacuum steam distillation up to 280° C. to produce the desired lubricant.

Voltolized oils possess many outstanding and desirable lubricating properties. They ensure excellent performance in internal combustion engines, high pressure compressors, superheated steam cylinders, marine engines, etc., because of their ability to remain fluid at relatively low temperatures and yet retain their viscosity at relatively high ones. Voltol oils are also very stable to heat and oxidation and in combustion engines deposit very little carbon or sludge in the oil sump. Deposits of sticky or hard residues usually noted on cylinder walls and valves of engines are generally absent when voltol oils are used. It has also been noted that the addition of a voltol oil to a mineral oil results in a very flat viscosity curve which is especially useful in the lubrication of airplane engines, internal combustion engines, and wherever wide temperature lubrication is required.

### Reduce Frictional Heat 25 to 55%

Due to their ability to form tenacious lubricating films on the surface lubricated, it has been noted that frictional heat is reduced from 25 to 55% and the efficiency of machines increased to a remarkable degree. Furthermore, it has been noted that voltol oils possess greater friction-reducing properties than any other animal, vegetable, or mineral oil of equal viscosity.

Both hydrogenation and voltolization of hydrocarbons, various oils, and organic materials form a large and important field for the production of lubricating products. The importance of developing and improving methods of producing synthetic lubricants by these processes cannot be over-estimated, even in a country like ours, which is the largest and most efficient producer of lubricating materials.

Lubricants are the life blood of machines, without which the wheels of industry and the machines of war cannot turn. It is of the utmost importance, therefore, that along with the commercial development of these processes for producing lubricants, fuels, etc., careful and exhaustive research should be conducted in order better to understand the various chemical and physical changes which occur during hydrogenation and voltolization reactions in order to develop better and more efficient methods of producing lubricants, fuels, etc., by these processes.

### Possibilities of Atomic Energy

Since the introduction of atomic energy, there has been a great deal of talk to the effect that coal and oil as sources of energy will soon be outmoded. Whether atomic energy can be harnessed and made commercially available in the near future is difficult to say. However, it is only in conjunction with a lubricating oil film that machines will be able to continue to operate. Therefore, it does not appear that the importance of lubricants will be diminished.

Our energy and ingenuity must never be relaxed in the search for new and better lubricating products.

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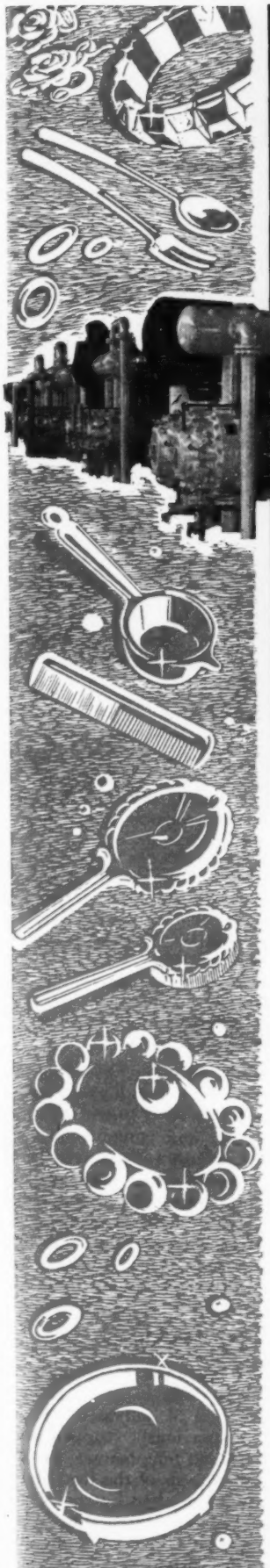

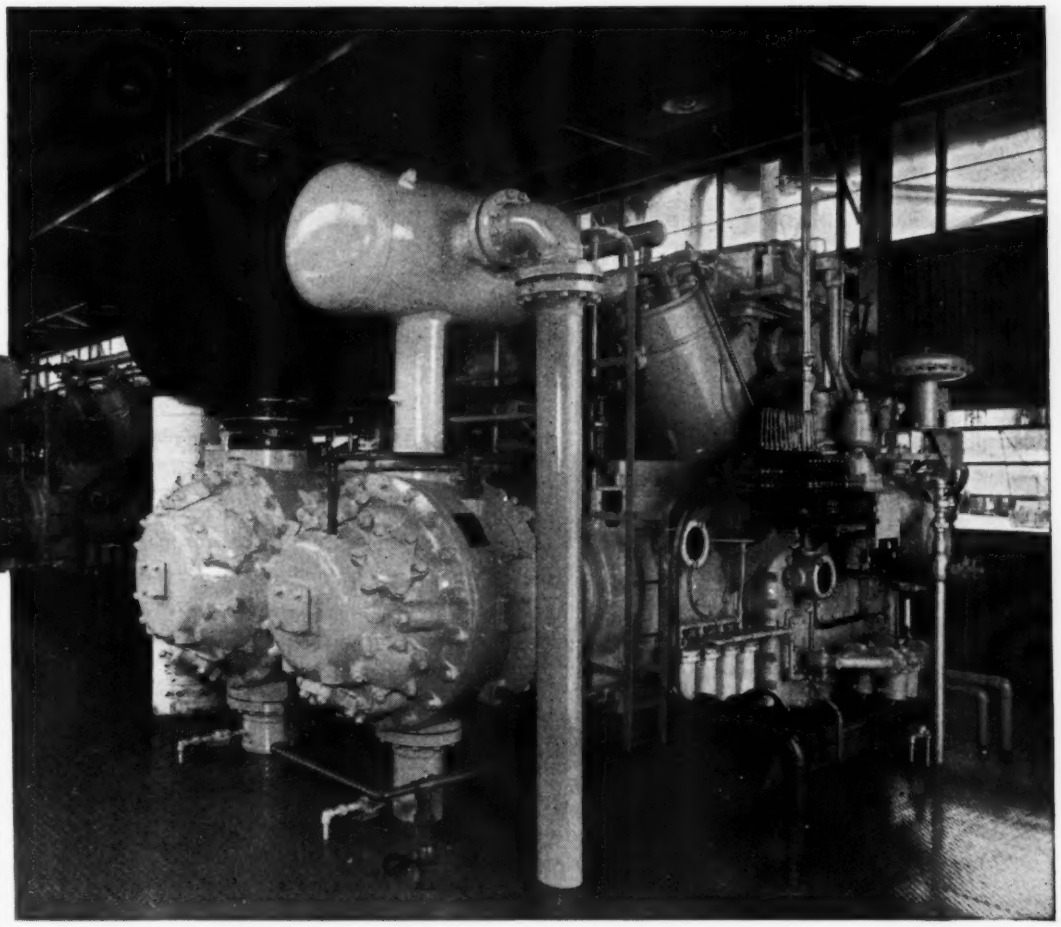

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# HYPERSORPTION Process for Separatio

**Adsorption of hydrocarbons from lean gas streams by the use of a moving bed of activated carbon, the Hypersorption process, achieves recoveries that would not be economic by conventional methods. Retentive qualities of activated carbon—compared to absorption oil they are as high as 90 to 1— are the basis of the process. Circulation of the carbon is by incorporation of a gas lift system in the hypersorption unit.**

**Pilot plant studies show low attrition losses in carbon, low steam consumption and high degree of purity. A wide range of applications in refineries and gasoline plants is indicated by the development work on the process. Union Oil Co. of California is the sole licensing agent for the Hypersorption process.**

HYPERSORPTION is essentially a fractionation process employing a moving bed of activated carbon to adsorb hydrocarbons from lean gas streams. The process, developed by Union Oil Co. and proved in extensive pilot plant work, is said to be practicable for the recovery of highly volatile or low concentration gases which would not be economic by conventional refining methods.

Operating advantages cited are: (1) elimination of compression and refrigeration facilities used in conventional recovery methods; (2) low steam consumption; (3) low attrition losses in the carbon and (4) high degree of recovery and purity of product. Possible applications include:

Recovery of valuable propylene and butylene from gas streams produced in high temperature cracking.

Recovery of $C_3$ and $C_4$ components from dry gas from natural gasoline absorption operations.

Separation of ethylene, in place of high-pressure, low-temperature demethanization.

Separation of hydrogen from mixtures of hydrogen, methane, $H_2S$ and heavier hydrocarbons.

Some applications in the recovery of volatile chemicals and solvents have been considered.

The basic process and economic factors which justified the development of the Hypersorption process stem from the characteristics of activated carbon as an adsorption medium.

The material is able to adsorb relatively large quantities of volatile hydrocarbons at low pressures. The duplication of such recovery by alternative means would involve high circulation of absortion oil or extremely low-temperature fractionation operations. This is illustrated in Table 1, showing the comparable retentions of activated carbon and a 200-molecular weight absorption oil, and the respective boiling points of the light hydrocarbons at the pressure of adsorption.

It will be seen that activated carbon is more effective by ratios as high as 90 to 1. The ratio becomes more favorable towards the lower pressure ranges. This is advantageous because separations directed toward high recovery and high purity must achieve reduction in partial pressure of the desired component in the effluent gas stream to the order of a fraction of a pound.

The cost of light hydrocarbon recovery processes involves as a principal factor the utility cost required to heat and cool the circulating medium. The low mass quantity of activated carbon required for a given recovery with the attendant utility economies constitutes one of the major justifications for its use.

The ability of activated carbon to retain trace quantities extends into the range of heavier hydrocarbons and chemical compounds. The advantages of these characteristics have been recognized generally in the use of activated carbon for solvent recovery and gas purification in fixed bed type units.

A distinctive feature of the process as compared to conventional recovery operations is that relatively low quantities of steam are used, on the order of 10 to 15 lbs. per 1000 lbs., of carbon circulated, which is a fraction of that normally encountered.

Attrition losses in the circulation of the carbon are said to be low, due to the free-flowing nature and homogeneous structure of the activated-carbon grains. An ultimate attrition loss rate of 0.0005% per cycle has been attained due to the design of the gas-lift system and the use of impactless separators in place of the conventional cyclones.

The Hypersorption unit is approximately equivalent to one high-pressure, low-temperature tower. It is said to eliminate refrigeration and compression facilities normally required by conventional recovery systems, and operates at the pressure level which most conveniently fits in with the attendant process operations. Pilot plant separations in the Hypersorber have been characterized by a high degree of recovery and purity of products.

### Process Described

The essential operation in the process involves contacting the feed gas stream with a moving bed of activated carbon which has been previously stripped and cooled to the desired temperature. Separation of the components of the feed takes place in the contacting bed by controlled selective adsorption of the heavier constituents. These are then subsequently stripped from the carbon at an elevated temperature by steam. The stripped carbon is returned to the top of the unit where it is dehydrated and cooled, then the cycle is repeated.

The Hypersorption unit, shown diagrammatically in Fig. 1, comprises two

**TABLE 1—Retention Capacities of Activated Carbon and Absorption Oil**

60-Minute Chloropicrin Activity Cocoanut Shell Activated Carbon
200 Molecular Weight Absorption Oil
Temperature of Adsorption—100° F.

| Hydrocarbon | Pressure Psia | Retention on Activated Carbon lb./lb. | Retention by Absorption Oil lb./lb. | Ratio of Adsorption to Absorption | Boil. Pt. ° F. |
|---|---|---|---|---|---|
| Methane | 1 | .00199 | .000022 | 90.5 | −300 |
| | 10 | .0075 | .00022 | 34.0 | −268 |
| | 25 | .0139 | .00055 | 25.2 | −249 |
| | 40 | .022 | .00088 | 25.0 | −237 |
| Ethane | 1 | .023 | .00027 | 85.0 | −198 |
| | 10 | .065 | .0027 | 24.1 | −140 |
| | 25 | .090 | .0068 | 13.2 | −110 |
| | 40 | .122 | .0107 | 11.4 | − 88 |
| Propane | 1 | .113 | .0014 | 80.7 | −136 |
| | 10 | .172 | .0140 | 12.3 | − 62 |
| | 25 | .186 | .0340 | 5.5 | − 20 |
| | 40 | .200 | .055 | 3.6 | − 2 |

# f Light Gases

major heat transfer sections, consisting of vertical tube-in-shell exchangers, separated by adsorption and rectifying sections with internals for introduction and take-off of the various gas streams.

These component parts are assembled to form one vertical cylindrical column with a cooler at the top and stripper at the bottom. A gas lift system is incorporated for circulating solids from the bottom of the unit to the top.

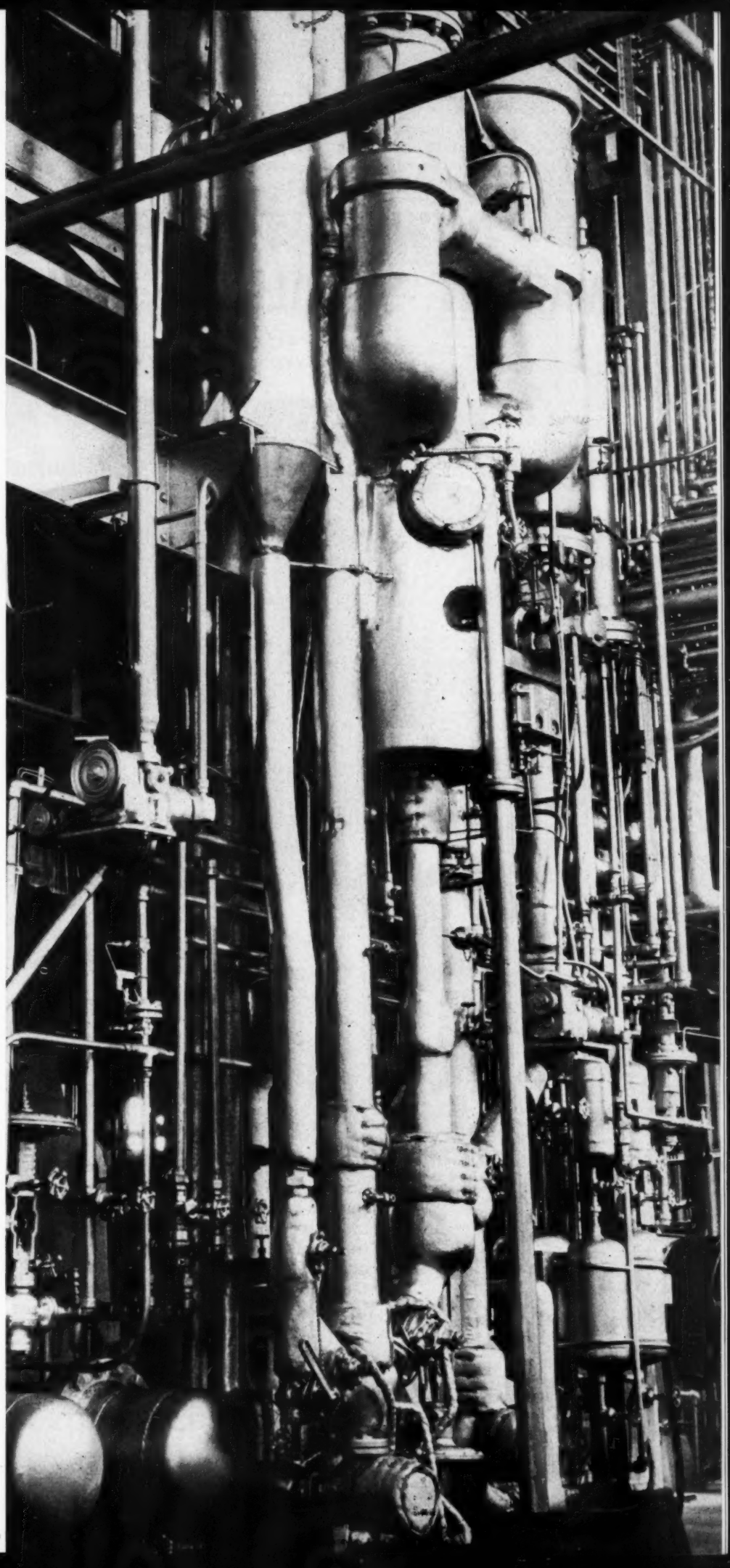
The column is filled with a bed of granular activated carbon, the upper level of which is maintained in a hopper at the top. This continuous bed moves slowly downward, and the circulation is controlled by the rate of release of the carbon from the base of the column into the lift system.

The carbon passes down from the hopper through vertical tubes where it is cooled prior to entrance to the adsorbing sections below. A gas stream simultaneously flows countercurrent to the carbon passing through the cooler and serves to remove effectively any vapor retained on the carbon from the stripping operation.

Feed gas is introduced through a distribution plate near the center of the adsorption section and passes upward countercurrent to the moving bed of carbon. The unadsorbed ligher components are discharged at the top of the adsorption section just below the cooler. The activated carbon below the feed point, which contains the adsorbed heavier components, passes downward to the rectifying section where it contacts a reflux of heavy constituents liberated by the stripper at the bottom of the unit.

This reflux serves to liberate any lighter constituents which may contaminate the adsorbed material. A concentration of intermediate constituents in the vapor phase develops in this section and, if desired, a disengaging tray may be located at this point to remove these intermediates as a sidecut.

The carbon flows downward through



**Hypersorption pilot plant at Union Oil Co. of California. Large cylindrical vessel at upper center contains adsorption, rectifying, and stripping sections. Pipe immediately to left of this vessel returns reactivated carbon to top of the unit**

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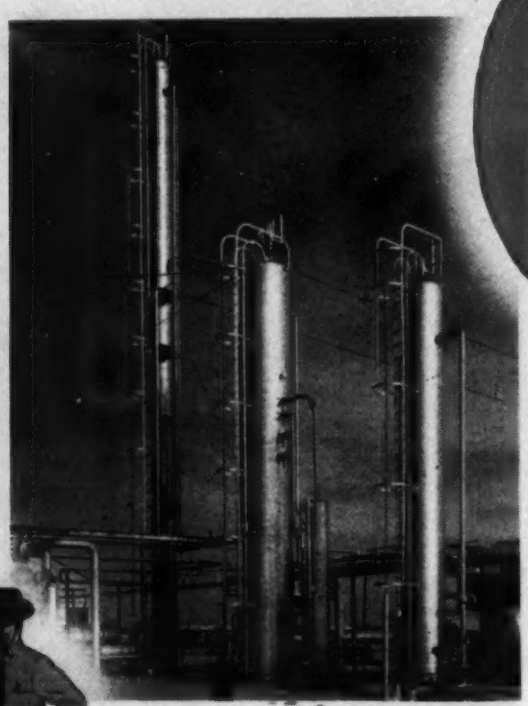

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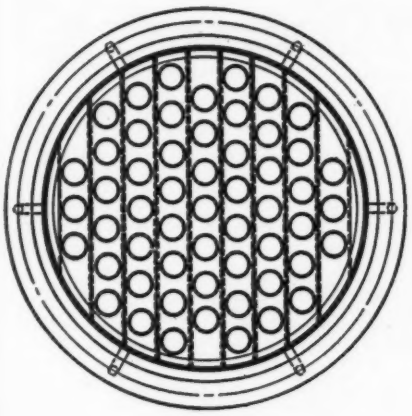


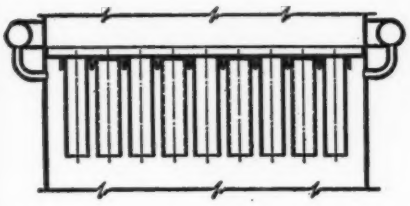


**Fig. 2—Construction details of engaging and disengaging trays**

a lower disengaging section and into a short steaming section directly above the stripper proper. There it meets an upward flow of steam liberating the adsorbed heavier components which are either produced as bottom product gas or returned to the rectifying section as reflux.

Steam introduced below the stripper passes countercurrent to the carbon flow in the vertical stripper tubes, through the steaming section, and is discharged with the bottom product gas. The increase in temperature of the carbon throughout the steaming and stripping section is gradual, with the highest temperature attained at the base of the stripper. Most of the adsorbed materials are removed before the carbon passes through the stripper tubes proper.

### Carbon Flow Carefully Controlled

The flow of carbon leaving the base of the unit is controlled by a specially designed feed mechanism which gives positive control of the flow distribution in the cross section of the unit. The carbon drops from this mechanism into a sealing leg which restricts the flow of steam into the lift system. It is then transported to the top of the tower and fed into the hopper.

For the purpose of maintaining a high level of activity, a reactivation unit is provided which circulates a small stream of carbon in parallel with the hypersorber, and carries out a high-temperature, steam-stripping operation to remove any accumulation of heavy residual hydrocarbons on the adsorbent.

The adsorption of gas on activated carbon is exothermic and, since heavier components are more readily adsorbed than lighter constituents, the temperature of the carbon bed is characteristic of the composition of the materials being adsorbed at any given point. Control of the separation in the unit utilizes this principle.

The sidecut and bottom make gas streams are governed by automatic temperature controllers which operate on the rather substanial temperature breaks corresponding to the separation points between the various classes of components being treated.

The basic concept of the design of the hypersorption unit is predicated upon positive control of the motion of solids in the unit. All the flow paths have been designed so as to be symmetrical across the area of the unit and to permit virtually vertical downward motion of the solids with mininum opportunity for channeling or unequal distribution.

The internals of the unit, consisting of engaging and disengaging trays, are constructed with a similar view and consist of circular plates having symmetrically placed downspouts through which the solids pass and under which the gases are permitted to engage or disengage. Typical construction is shown in Fig. 2. The respective amounts of area inside and outside the downcomers

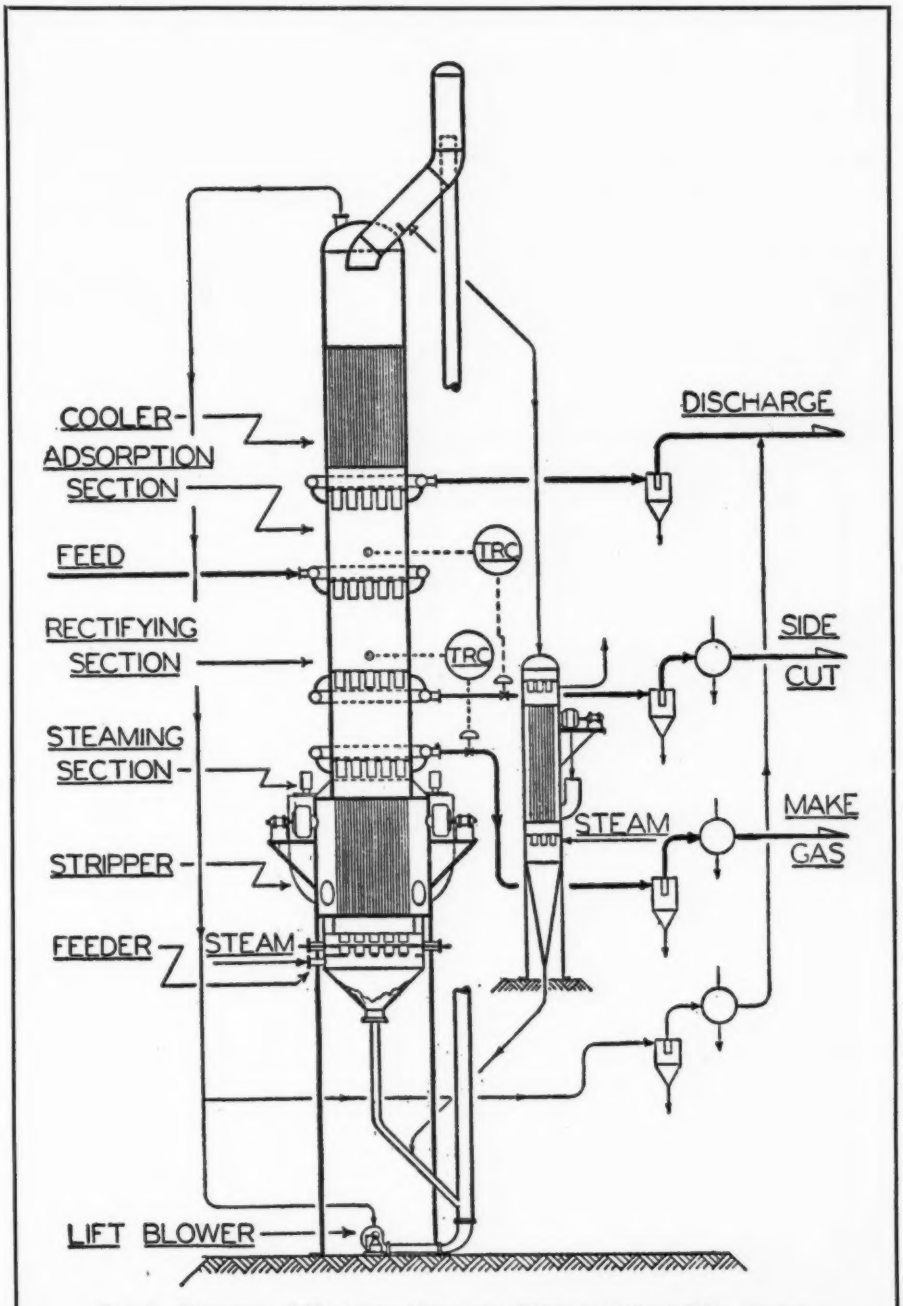



**Fig. 1—Diagram of Hypersorption unit. Flow is indicated by arrows**

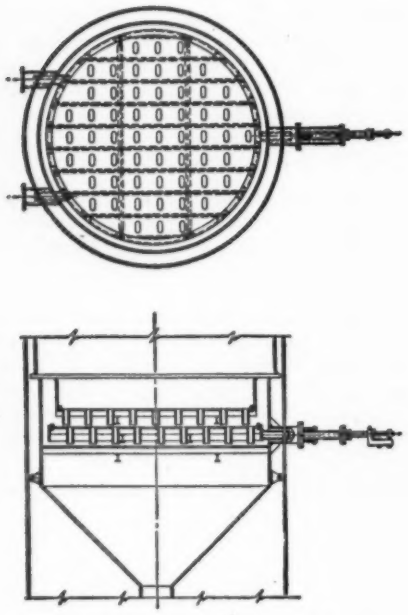


Fig. 3—Construction details of flow control mechanism

are proportioned in accordance with the flow quantities of gas being removed or introduced. A number of inlet or outlet points is employed around the ring tube to minimize pressure drop in the gas distribution across large diameter trays.

The flow control mechanism at the bottom of the stripper is of the positive displacement type, assuring equal flow throughout the cross-sectional area. As illustrated in Fig. 3, it consists of a circular tray supported at three points and given an oscillating motion.

The tray has a number of downspouts which serve as pockets for the conveyance of solids. When in one extreme of its motion, alternate downspouts of this tray are in position to be filled by the delivery tubes in the fixed tray above. These pockets do not discharge, because in this position they are sealed by the tray below. As the tray moves to the opposite extreme in its travel, these downspouts pass into position over discharge holes in the tray below and are emptied.

### Similar to Convention Fractionation

The separation of hydrocarbons in a Hypersorption unit is a fractionation process involving the countercurrent contacting of the hydrocarbon components in the two phases, and is quite analogous to the conventional multi-component fractionation processes.

The factors of reflux ratio, stage number, and variable molal flow of phases are of importance, together with controlling adsorption effects of activated carbon which dictate the relative volatility of the components and thereby the separations occurring in each stage of contact.

Fig. 4 shows a typical vapor-pressure chart for propane in which temperature and percent saturation of the carbon are the determining variables. The factor "percent saturation" represents the percent of the available adsorption volume filled by the liquefied hydrocarbon phase. In the case of hydrocarbons above their critical temperature, this term refers to the volume occupied by the high density, adsorbed gas phase.

The design of a column for the separation of hydrocarbons reduces itself to a calculation analogous to that involved in multicomponent fractionation for the case of variable molal overflow with the added variable of change in relative volatility of the components in each stage as a function of the quantity and composition of the adsorbed phase. For every separation a minimum reflux ratio and minimum number of stages are required.

In Fig. 5 is presented a plot of stagewise calculations evaluating the separation between ethane and propane in a Hypersorption bed, feeding a lean gas stream consisting largely of methane and $C_2$, with heavier components being present in a relatively small quantity. The

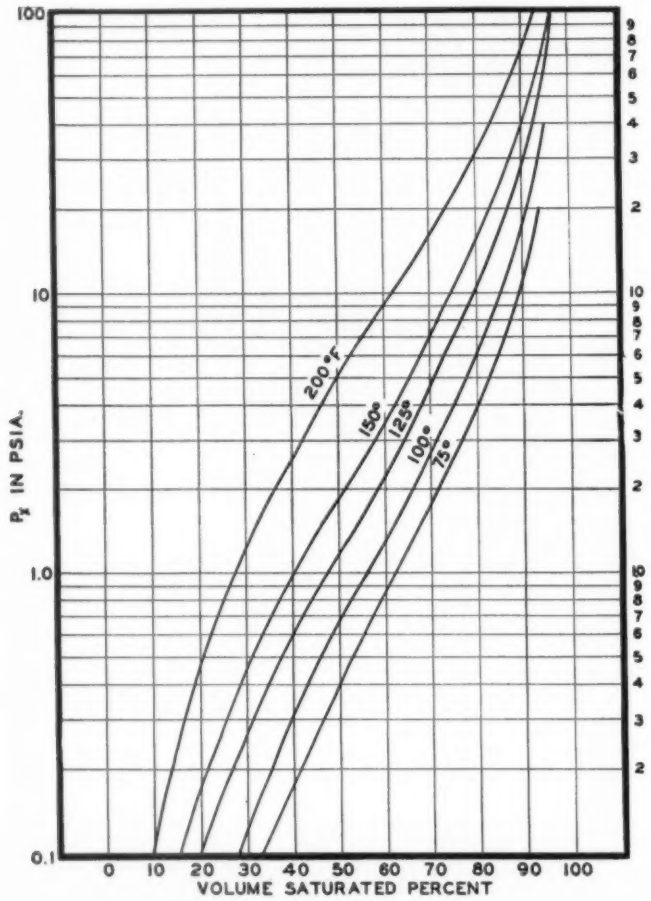
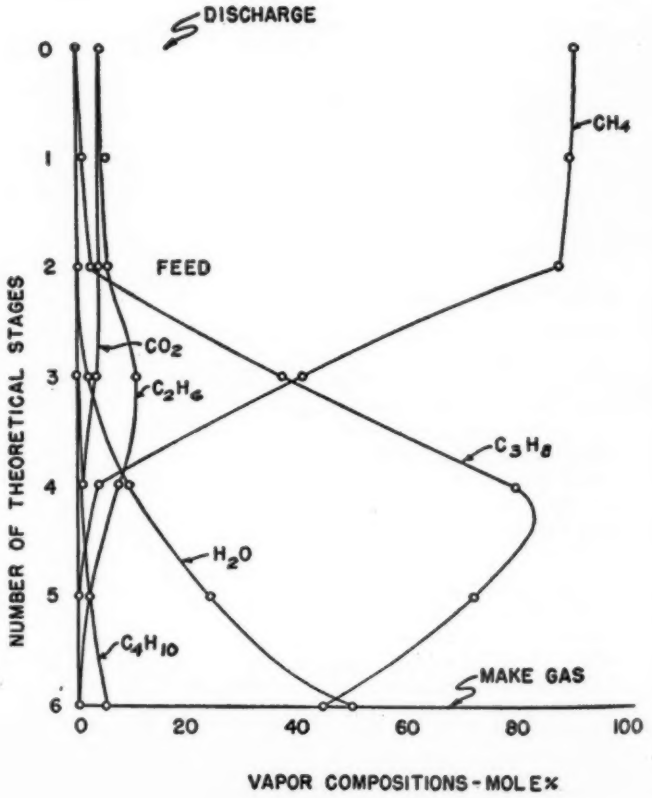



Fig. 4—Vapor-pressure chart for propane

Fig. 5—Plot of stagewise calculations for separation of ethane and propane



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compositions of feed and production streams are given in Table 2.

**Other Separations**

Pilot plant operations have included the separation of hydrogen from mixtures of hydrogen, methane, hydrogen sulfide and heavier hydrocarbons. Gas streams of this character are obtained from hydroforming plants and special cracking operations. In the separation of hydrogen from such streams, a once-through operation is employed, hydrogen being taken overhead and methane and heavier hydrocarbons recovered as bottoms product from the unit. As shown in Table 3, it will be noted that a very high-purity hydrogen is readily obtained in this operation.

In the purification of ethylene, the Hypersorption unit takes the place of the high-pressure, low-temperature demethanizer used in the conventional plant. Normally a sidecut containing the $C_2$ components is taken off the hypersorber. Methane and hydrogen are produced as overhead, and $C_3$'s and $C_4$'s are produced as bottoms. Typical separations of ethylene in pilot plant operations both with and without sidecutting are shown in Table 4. In these separations a recovery of 98% (or better) of the etheylene in the feed stream is usually obtained.

If the $C_3$ content of the feed stream reaches a high value, appreciable contamination of the sidecut stream with

**TABLE 2—Composition of Streams in Hypersorption Separation of Ethane and Propane (in Mole %)**

| Component | Feed | Discharge | Make Gas |
|---|---|---|---|
| $CH_4$ | 88.0 | 90.65 | .... |
| $CO_2$ | 4.5 | 4.63 | .... |
| $C_2H_6$ | 4.5 | 4.62 | 0.33 |
| $C_3H_8$ | 2.7 | 0.10 | 89.37 |
| $C_4H_{10}$ | 0.3 | ... | 10.30 |
| Feed | 100 mole. | | |
| Discharge | 97.09 mole. | | |
| Make Gas | 2.91 mole. | | |

**TABLE 3—Separation of Hydrogen and Methane in Pilot Plant Operations**

| Component | Feed | Make Gas | Discharge |
|---|---|---|---|
| $H_2$ | 52.2 | Trace | 100.0* |
| $C_1$ | 43.5 | 91.0 | .... |
| $C_2$ | 2.7 | 5.6 | .... |
| $C_3$ | 1.6 | 3.4 | .... |

* Mass spectrograph analysis.

**TABLE 4—Separation of Ethylene in Pilot Plant Operations**

Without Sidecutting

| Component | Feed | Make Gas | Discharge |
|---|---|---|---|
| $C_1$ | 43.0 | 1.6 | 99.1 |
| $C_2$ | 49.5 | 85.9 | 0.2 |
| $C_2$ | 5.5 | 9.3 | 0.4 |
| $C_3$ | 2.0 | 3.2 | 0.3 |

With Sidecutting

| Component | Feed | Sidecut | Make Gas | Discharge |
|---|---|---|---|---|
| $C_1$ | 40.1 | 0.5 | Trace | 99.6 |
| $C_2$ | 18.9 | 32.8 | 0.3 | 0.3 |
| $C_2$ | 37.9 | 65.9 | 1.2 | 0.1 |
| $C_3$ | 3.1 | 0.8 | 98.5 | Trace |

TABLE 5—Comparison of Straight and Rectified Sidecutting Operations in Pilot Plant

Straight Sidecutting

| Component | Feed | Sidecut | Make Gas | Discharge |
|---|---|---|---|---|
| $C_1$ .... | 37.9 | 0.3 | Trace | 99.4 |
| $C_2$ .... | 19.2 | 57.5 | 0.2 | 0.3 |
| $C_2$ .... | 11.5 | 34.1 | 0.9 | 0.1 |
| $C_3$ .... | 27.9 | 7.7 | 87.3 | 0.2 |
| $C_4$ .... | 3.5 | 0.4 | 11.6 | Trace |

Rectified Sidecutting

| Component | Feed | Sidecut | Make Gas | Discharge |
|---|---|---|---|---|
| $C_1$ .... | 37.6 | 2.3 | ... | 99.6 |
| $C_2$ .... | 29.8 | 86.6 | Trace | 0.2 |
| $C_2$ .... | 3.5 | 10.1 | Trace | 0.1 |
| $C_3$ .... | 28.8 | 0.8 | 99.2 | 0.1 |
| $C_4$ .... | 0.3 | 0.2 | 0.8 | Trace |

TABLE 6—Recovery of $C_3$ and $C_4$ Components from Absorber Dry Gas in Pilot Plant Operations

| Component | Feed | Make Gas | Discharge |
|---|---|---|---|
| $C_1$ ..... | 92.2 | 1.2 | 95.2 |
| $C_2$ ..... | 4.6 | 0.7 | 4.7 |
| $C_3$ ..... | 2.9 | 87.0 | 0.1 |
| $C_4$ ..... | 0.3 | 11.1 | Trace |

$C_3$'s occurs, and it is preferable to use a rectified sidecut operation which employs a modified tray construction in the section below the feed point. A comparison of the separations with the two types of sidecutting operations on feed streams containing a high $C_3$ content is shown in Table 5.

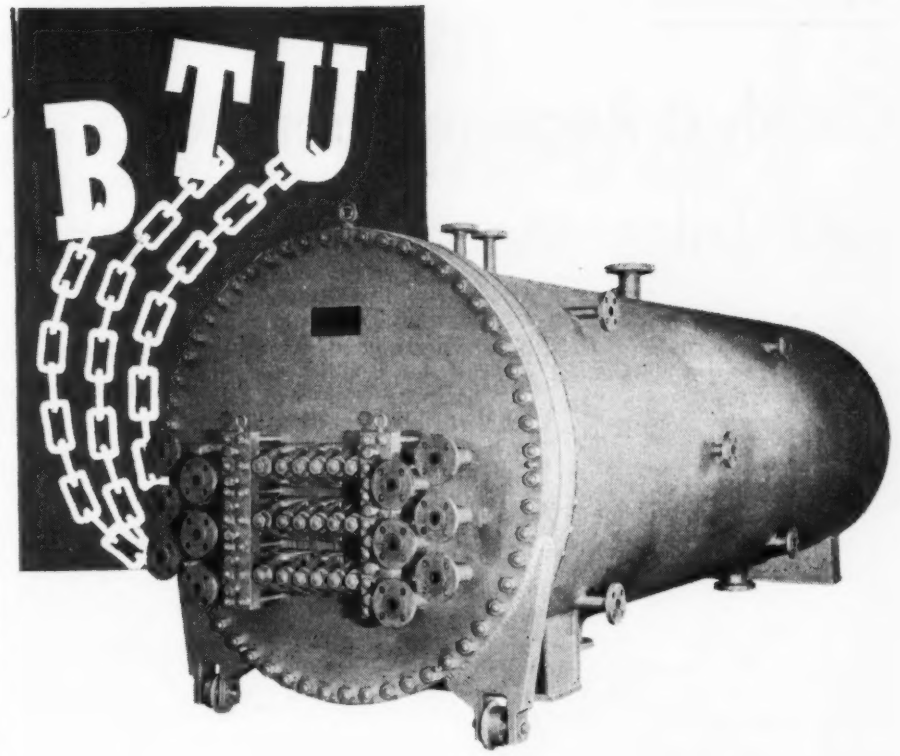
If complete removal of $C_3$'s is desired a second hypersorption unit normally will be required. If separation of the ethane from the ethylene is desired, the sidecut stream is compressed and ethylene separated in a small refrigerated column. However, gas produced in high-temperature, gas oil cracking will frequently show a high ratio of ethylene to ethane and further processing of the sidecut stream may not be necessary.

Gas streams produced in high temperature cracking operations, or oil absorber effluent streams derived from thermal or catalytic cracking contain low concentrations of valuable propylene and butylene difficult to recover by conventional means.

The dry gas from natural gasoline absorption operations normally contains appreciable quantities of $C_3$'s and $C_4$'s. The pilot plant has demonstrated high recoveries of these constituents. Table 6 shows typical results obtained from absorber dry gas.

**Acknowledgement**

This article is based on a paper under the same title by Clyde Berg, Supervisor of Process Development, Research Department, Union Oil Co. of California, presented before the American Institute of Chemical Engineers, Houston, March 31-April 3, 1946.

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The control of catalyst regeneration in both the Thermofor and Fluid catalytic cracking processes was the subject of two among several technical papers of interest to refiners presented at the Spring Meeting of the American Society of Mechanical Engineers in Tulsa, March 2-5.

Topics of other papers covering problems confronting refiners and natural gasoline plant operators included: the synthesis of hydrocarbons from natural gas; testing and studying operation costs of centrifugal pumps; fabrication of corrosion-resistant alloys; comparable fatigue tests of welding elbows and double-mitre bends; electrical and mechanical power requirements in oil refineries.

Nearly every phase of mechanical engineering was considered during the four day meeting. A total of 23 technical papers and four general addresses were delivered during 13 sessions. More than 250 engineers were registered and an estimated 350 attended the various sessions.

Important points of some of the papers are reviewed in the digests presented below.

## *Factors in Regeneration of Synthetic Bead Catalysts in Thermofor Cracking Process*

*"Combustion of Coke Deposit on a Synthetic Bead Cracking Catalyst," by W. A. Hagerbaumer, Socony-Vacuum Oil Co., Inc., New York, and Russell Lee, Socony-Vacuum Oil Co., Inc., Paulsboro, N. Y.*

ALTHOUGH there are several feasible methods for regenerating catalysts in moving bed type catalytic cracking systems, process, engineering, and economic considerations led to the development of a "multizone" type of kiln for use in the Thermofor Catalytic Cracking process. In the multizone kiln, coke is burned from the catalyst in a series of zones with temperature control being effected by cooling coils located at various levels in the kiln.

Critical analysis of the problem of burning coke from a flowing bed of catalyst revealed the following main factors for evaluation:

1. Coke Deposit:
   a) Initial carbon concentration on the catalyst.
   b) Fraction of the initial carbon deposit remaining on the catalyst.
   c) Relative proportions of carbon and hydrogen.
2. Operating Conditions:
   a) Temperature.
   b) Air rate.
   c) Oxygen concentration.
   d) Catalyst volume in burning zone.

The type of equipment used to study multistage burning of coke deposits is shown in Fig. 1. Coke-bearing catalyst, obtained from a TCC reactor, was passed repeatedly through an adiabatic combustion chamber until substantially all the carbon was burned off.

Three combustion chambers, having effective catalyst volumes of 0.13, 0.26 and 0.52 cu. ft., were used. These chambers provided 2.5, 5 and 10 min. catalyst residence times, respectively, at the catalyst flow rate employed. All were equipped for countercurrent flow of catalyst and air.

In conducting the experimental work the initial carbon concentration was controlled at 1, 3, and 6 %-wt. and the atomic ratio of hydrogen to carbon in the coke deposit was varied from 0.3 to 1.0 by altering the operating conditions of the cracking reactor. Study of the effects of kiln operating variables was made using temperatures ranging from 750 to 1150° F. and air rates ranging from one to 16 cfm per cu. ft. of catalyst volume. All regenerations were conducted at atmospheric pressure, which is substantially the condition in commercial TCC kilns.

The laboratory data on the rate of combustion of carbon from flowing beds of bead catalyst at atmospheric pressure were correlated by the relation,

$$W = O_m \cdot f_1(T) \cdot f_2(C_o) \cdot f_3(C/C_o)$$

where:

$W$ = Carbon burning rate, lb. carbon per hr. per cu. ft. of catalyst bed.

$O_m$ = Log mean of the oxygen concentrations of the air entering and the flue gas leaving a burning zone, mol fraction.

$f_1(T)$ = empirical function of average catalyst temperature, $T$, °F.

$f_2(C_o)$ = empirical function of initial carbon concentration, $C_o$, %-wt.

$f_3(C/C_o$ = empirical function of the fractional carbon contration.

$C$ = average %-wt. carbon on catalyst in a burning zone.

Preliminary examination of the data revealed that for approximately constant conditions of temperature, initial carbon

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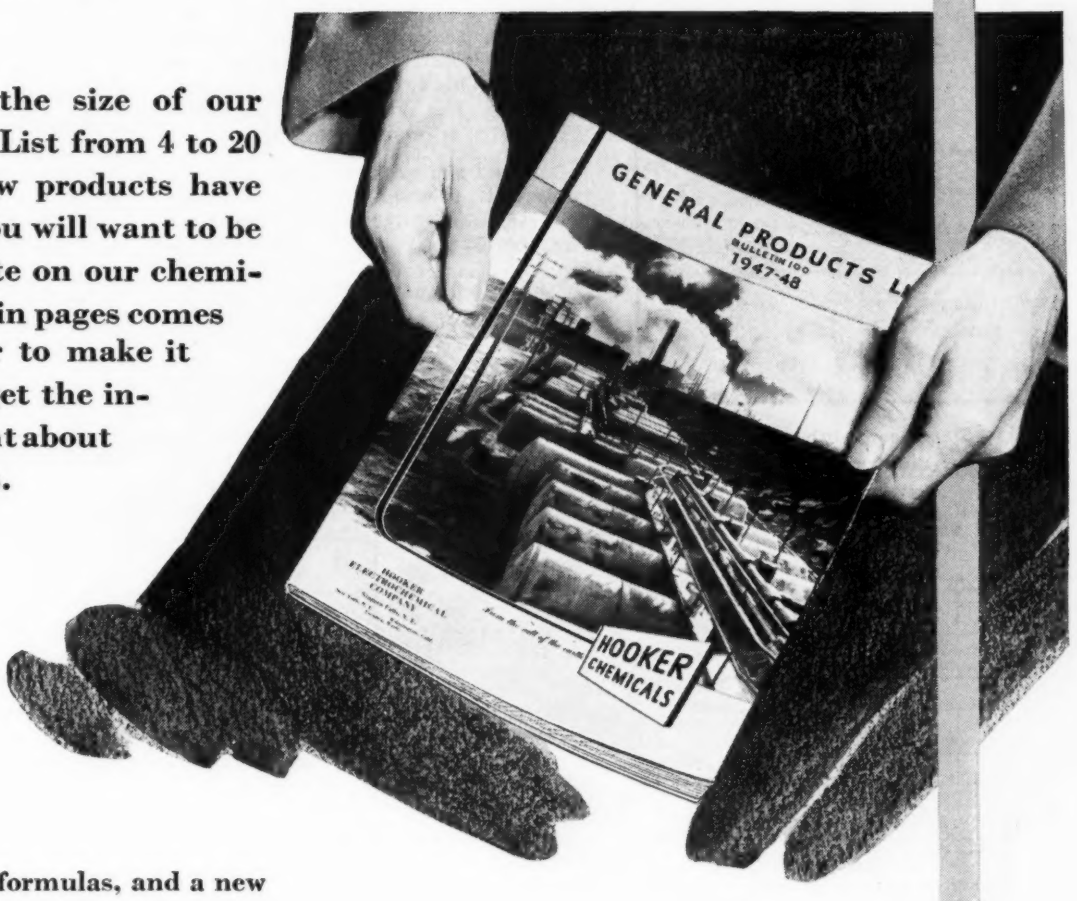


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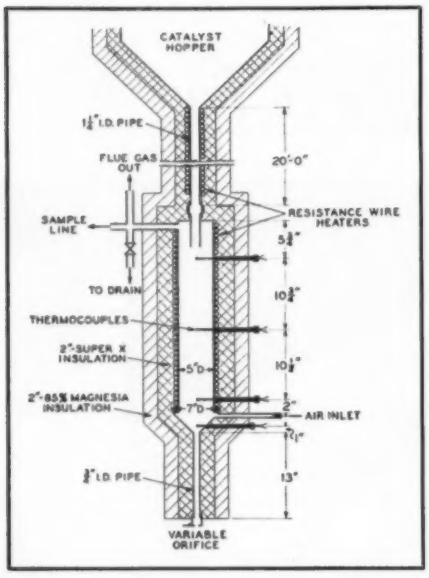



**Fig. 1—Single-zone laboratory kiln arranged for multizone studies on catalyst regeneration**

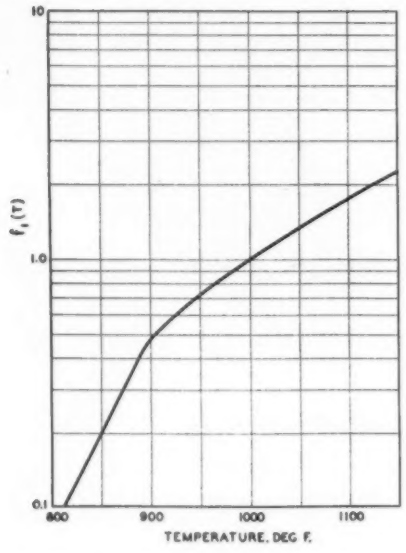



**Fig. 2—Effect of temperature on carbon burning rate**

concentration, and fractional carbon concentration; the carbon burning rate, $W$, varied directly with the log mean oxygen concentration, $O_m$. This direct relationship between $W$ and $O_m$ thus permitted the use of the quantity $W/O_m$ in evaluating the effects of the other terms in the equation.

A series of successive approximations was made to determine the individual effects of temperature, initial carbon concentration, $C_o$, and fractional carbon concentration, $C/C_o$, on the quantity $W/O_m$. At the beginning $W/O_m$ was plotted versus $C/C_o$ for each of the three levels of $C_o$ employed in the experimental work, namely 1, 3 and 6 %-wt. These plots were studied to obtain a preliminary appraisal of the effect of temperature on $W/O_m$.

Thus from these data a chart was made by plotting $W/O_m$ versus temperature for constant values of $C/C_o$ and $C_o$. A series of parallel curves resulted. These curves were resolved into a single curve expressing tentatively relative burning rate as a function of temperature and having arbitrarily a value of unity at 1000° F. The final plot of this function, $f_1(T)$, is presented in Fig. 2.

A second plot was then made of $W/O_m$ versus $C/C_o$ in which the observed values of $W/O_m$ were corrected to the base temperature of 1000° F., as illustrated in Fig. 3. This revealed that the curves for each level of initial carbon concentration, 1, 3 and 6 %-wt., were parallel and hence the effect of $C_o$ on $W/O_m$ was constant for all values of $C/C_o$.

The effect of $C_o$ on $W/O_m$ relative to a fixed $C_o$, taken arbitrarily as 3 %-wt., was next evaluated by adjusting the experimental values of $W/O_m$ for each coke deposit investigated to 1000° F. and constant $C/C_o$ using tentative forms of Figs. 2 and 3, respectively. Charts resembling Fig. 4 were obtained. Fig. 4 was then used to adjust all experimental values of $W/O_m$ to fixed values of $C_o$ (3.0 %-wt.) and temperature (1000° F.) to obtain a curve similar to Fig. 5 evaluating $f_3$ $(C/C_o)$.

The evaluations of the three functions were made more precise by successive approximations in which deviations associated with any particular variable were eliminated. Figs. 2, 4 and 5 are the

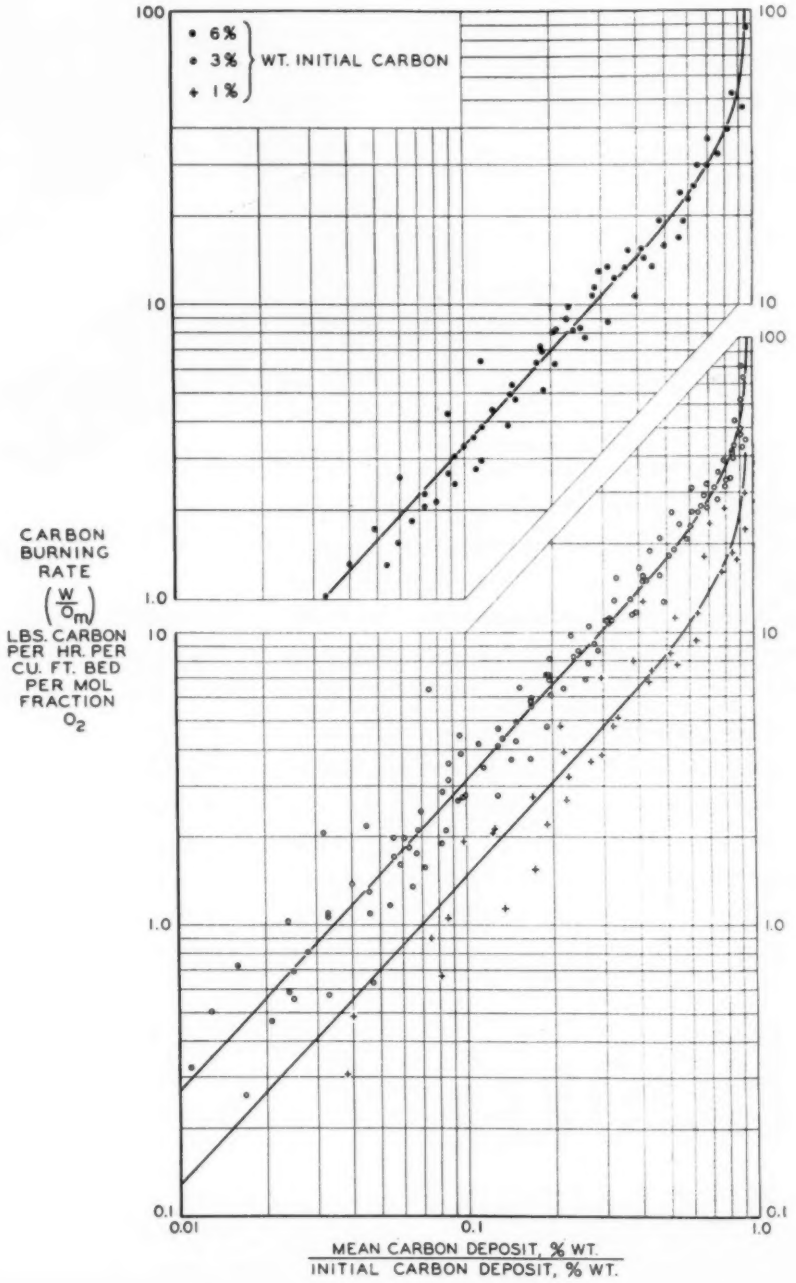



**Fig. 3—Carbon burning rate corrected to 1000° F.**

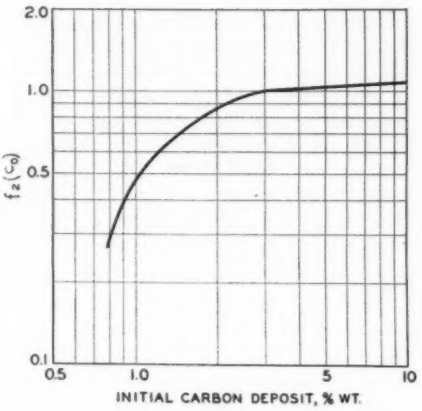



Fig. 4—Effect of initial carbon deposit on carbon burning rate

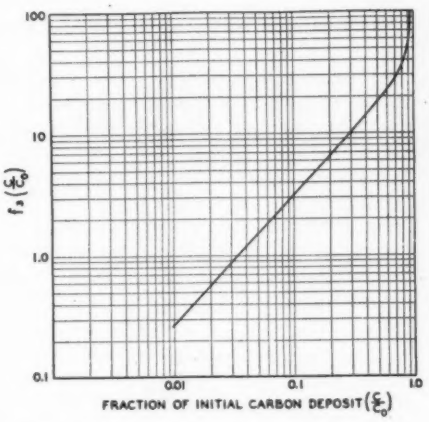



Fig. 5—Effect of fractional carbon concentration on carbon burning rate

final charts evaluating the functions in the equation, $f_1(T)$, $f_2(C_o)$ and $f_3\ C/C_o$, respectively.

It is interesting to note that the apparent activation energy for carbon deposits, calculated from Fig. 2 for the temperature range from 800 to 900° F. where the change in the rate of combustion with temperature appears to be influenced only slightly by gas diffusion rates, is of the order of 35,000 calories per gram-mol as compared to 44,000 calories per gram-mol found by Parker and Hottel for the combustion of brush carbon.

# Close Control Important in Regenerating Spent Catalyst in Fluid Cracking Units

*"Regeneration of Spent Catalyst in Fluid Catalytic Cracking," by John F. Snuggs, Standard Oil Co., (Indiana), Whiting, Ind.*

REGENERATION of spent catalyst under closely controlled conditions is an important feature of the Fluid catalytic cracking technique. Although only about 1 to 2 %-wt. of carbonaceous material collects on the catalyst, the combustion in the regenerator contributes a major portion of the heat required in the reactor for hydrocarbon conversion, and residual heat usually used to make steam. Typical heat distribution in a commercial unit is shown in Table 1.

Principal variables affecting the design of a Fluid regeneration system are:

1. Temperature of regeneration.
2. Type of catalyst.
3. Analysis of catalyst deposit.
4. Fraction of catalyst deposit removed during regeneration.
5. Contact of air and catalyst, and catalyst residence time.
6. Regeneration pressure.

Choice of operating temperatures is a balance among several factors. In general, the higher the temperature, the more readily combustion occurs. On the other hand, at the highest temperature levels, permanent catalyst deactivation occurs at an accelerated rate, and construction problems and costs tend to become a more important consideration. Current designs generally call for a temperature range of 1025 to 1100° F.

The type of catalyst used is important because of temperature deactivation problems. It also affects air requirements and heat evolution, since catalysts of different chemical compositions result in various $CO_2$ to CO ratios in effluent regeneration gases. With various commercial catalysts this ratio varies between about 50:50 to 65:35. Air requirements at various ratios are given in Table 2.

The presence of certain metallic contaminants which may accumulate on the catalyst during operation tends to increase the $CO_2$ to CO ratio, and results in increased air requirements.

Since about four times as much air is required to burn one pound of hydrogen as is necessary for one pound of carbon, the importance of adequate stripping facilities and low hydrogen content in determining regeneration air requirements is obvious. Normally, with a well designed stripper, slightly less than 10 %-wt. of hydrogen in coke can be specified for design purposes.

The weight per cent of catalyst deposit on spent catalyst charged to the regenerator varies between less than 1 to more than 2% in commercial installations, and is partially a function of the catalyst-to-oil ratio fed to the cracking zone. Regenerated catalyst contains from about 0.3 to 1.0 %-wt. of residual deposit after combustion.

Several factors define the coke level desired on any specific design. First, combustion proceeds more readily on catalyst with a high deposit content than on that with a low coke content. Second, from the standpoint of the cracking side, a low coke content is desirable. Third, high coke percentages in the regenerator are not satisfactory because catalyst entrainment in flue gas tends to increase. Commercial practice has established a

**TABLE 1—Distribution of Regeneration Heat in a Commercial Fluid Unit**

| | Millions of Btu/hr. | Per Cent |
|---|---|---|
| Heat released | 238 | 100 |
| Heat in flue gas (over entering air)* | 56 | 23 |
| Heat to reaction zone | 36 | 15 |
| Heat to steam | 125 | 53 |
| Loss and unaccounted for | 21 | 9 |
| Total | 238 | 100 |

**BASIS**

Operations as shown in Table 3.
Net heat of combustion of coke is 13,840 Btu/lb. at 8% hydrogen.
Reaction zone temperature is 900° F.
Steam produced at 160 psig. from 300° F. boiler feed water.

* Approximately 50% of this heat potentially recoverable in a flue gas boiler, bringing steam to 153 million Btu/hr., or 64% of heat release.

**TABLE 2—Combustion Air Requirements . . in Fluid Catalytic Cracking . .**

| Ratio $CO_2$/CO in Combustion Gas | Wt.-% Hydrogen in Catalyst Deposit* | Combustion Air Requirement—Lbs. Air/Lb. Deposit Burned |
|---|---|---|
| 50:50 | 8 | 12.05 |
| 65:35 | 8 | 12.92 |
| 50:50 | 12 | 13.18 |
| 65:35 | 12 | 14.02 |

**BASIS**

2% oxygen in dry effluent flue gas.
Air supplied at 100° F., 50% Relative Humidity.

* Measured by oxygen disappearance in regenerator as determined from Orsat analysis and nitrogen balance.

**TABLE 3—Regenerator Operation in a Typical Fluid Catalytic Cracking Unit**

| | |
|---|---|
| **Design Details** | |
| Vessel Diameter | 36'-6" I.D. |
| Shell length | 40'-0" |
| Heads | Hemispherical |
| Top elevation | 150' |
| Shell and heads | Carbon steel |
| **Operating Conditions** | |
| Pressure at top of vessel | 9 psig. |
| Catalyst bed temperature | 1025° F. |
| Entering air temperature | 230° F. |
| Catalyst bed depth | 18' |
| Catalyst bed density | 20 lbs./cu. ft. |
| Spent catalyst charge | 540 tons/hr. |
| Air supplied | 220,000 lbs./hr. |
| Gas velocity at top of vessel | 1.45 ft./sec. |
| Carbon on spent catalyst | 1.80 w.t.-% |
| Carbon on regenerated catalyst | 0.35 wt.-% |
| Coke burned (8% hydrogen) | 17,200 lbs./hr. |
| Flue gas analysis (dry) | |
| $CO_2$ | 12.0 vol.-% |
| $O_2$ | 2.0 vol.-% |
| CO | 5.8 vcl.-% |
| Inert | 80.2 vol.-% |
| Steam produced | 135,000 lbs./hr |

desirable coke content of 0.3 to 0.7 %-wt., to be maintained by control of other operating variables.

Another important factor is the provision of a suitable distributing device to promote adequate contacting of air and catalyst within the regenerator. It is also desirable to avoid a shallow catalyst bed through which mass channeling of air may occur. In large commercial units, at least 10, and preferably 15, ft. of bed depth are desired where the regenerator takes the form of a single bed.

Gas should flow through at low velocity—the usual commercial designs calling for about 1.5 ft./sec., satisfactory for minimizing catalyst entrainment.

Catalyst residence time need not exceed 5 min., but because of the effect of other necessary design factors, it usually ranges between 10 and 20 minutes.

Operating pressures vary between about 1 and 13 psig. With specified maximum allowable gas velocities, the higher pressures permit smaller diameter vessels in new designs or greater air flows in existing units. It should be noted, however, that combustion proceeds more favorably at the higher pressure levels, which factor must, of course, be balanced against increased compression equipment costs.

A number of variations in control technique have been used in Fluid units. The conventional methods were described. Table 3 summarizes some design and operating data for a commercial Fluid regenerator. The data, it is pointed out, are for a specific installation and are not typical of all units.

# Processes for Hydrocarbon Synthesis from Natural Gas Show Much Economic Promise

*"The Manufacture of Synthetic Gasoline," by George Roberts, Jr. and J. A. Phinney, Stanolind Oil & Gas Co., Tulsa.*

DEVELOPMENTS leading to the initial commercial application of the Fischer-Tropsch synthesis to the manufacture of gasoline are outlined, including status of German practice, engineering aspects of the German plants and proposed plants in the U. S. Since much of this material is taken from the literature, this review is concerned mainly with the proposed plants in this country, notably that of Stanolind Oil & Gas Co. in the Hugoton Field of Kansas and Carthage Hydrocol, Inc., at Brownsville, Texas.

The proposed American plants will make use of the basic technique in catalitically combining carbon monoxide and hydrogen to form hydrocarbons and water. First important variation is preparation of these two gases by catalytic reforming of methane, steam, and carbon dioxide to form carbon monoxide and hydrogen in a fired furnace at 1500° F. and atmospheric pressure.

An alternative method, as yet not used commercially but which shows greater economic promise, is the partial combustion of preheated methane and oxygen at 300 psi and 2500° F. This method is desirable because it supplies large quantities of by-product heat, can be carried out at pressures required in the synthesis following, and natural gas usually is available at that pressure. A schematic diagram of a proposed plant using this method is shown in Fig. 6.

The reacting gases are cooled and enter the synthesis reactor at approximately 600° F. and 250 psi, where they contact a fluidized iron-type catalyst. Following synthesis, gases are again cooled and recovery of liquefiable hydrocarbons is carried out under 200 psi by conventional oil absorption techniques. Light olefins will be polymerized to make a high octane blending agent.

Efficiency of utilization of carbon in natural gas is considerably higher than that attained by the Germans using a cobalt catalyst. The German yields were of the order of 37 gal. synthetic product, containing 203 lbs. carbon as oil and chemicals, from 1000 lbs. of coke containing 800 lbs. carbon. The American version will secure 42 gal. of product containing 230 lbs. carbon as oil and chemicals from 10,000 cu. ft. of natural gas containing 342 lbs. carbon.

The proposed American reactors will be good for 1000 b/d synthetic oil; hence six reactors for a 6000 b/d plant which, with all necessary utilities, will cost between $3000-$3500 per daily barrel of hydrocarbon product. The standard German design, using the cobalt catalyst, produced but 18 b/d per reactor, thereby requiring 300 reactor units for a 6000 b/d plant; investment involved was $7500-$8000 per daily barrel. The usual German plant had 72 reactors, produced 1300 b/d product.

Investment and manpower requirements for the process have been greatly reduced by the use of the fluidized technique for contacting reacting gases with catalyst. Moreover, the improved iron catalyst produces a much higher grade of gasoline (premium 80 O. N.—not stated whether Motor or Research basis) than the German cobalt catalyst.

Since it has been determined that reaction temperature rather than catalyst activity controls quality of product, the fluidized technique is doubly important as close control of temperature and ready removal of large quantities of heat are easily attainable, permitting a much larger reactor and more efficient operation than its German counterpart.

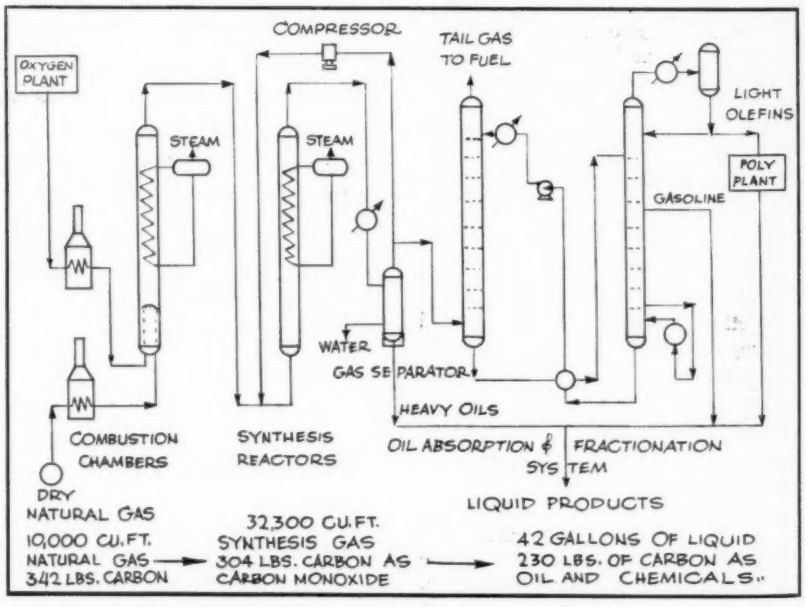
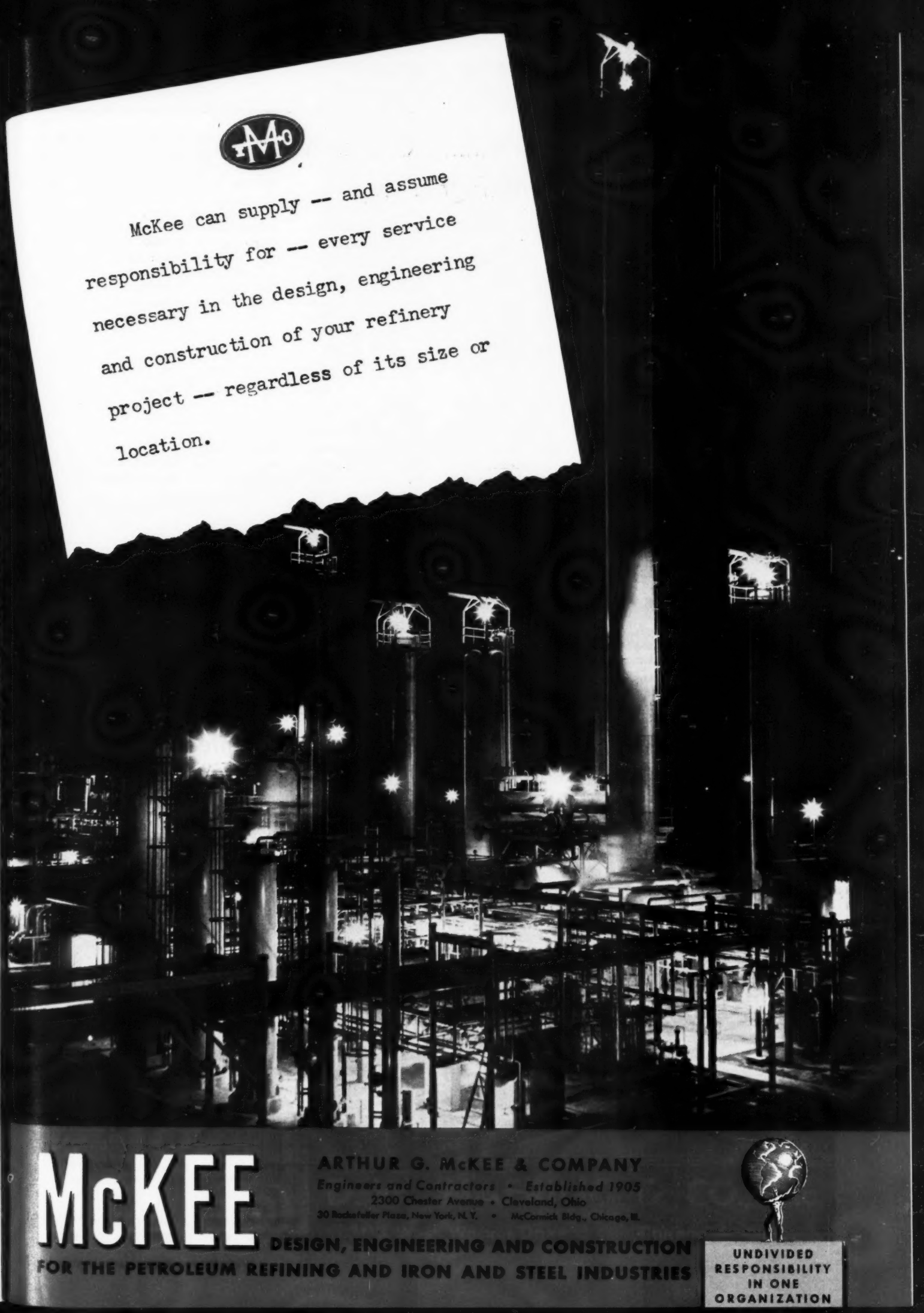



**Fig. 6—Schematic diagram of proposed American application of Fischer-Tropsch process to the manufacture of synthetic gasoline**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# Describe Method for Determining Optimum Time for Overhauling Centrifugal Pumps

*"A Method for Testing and Studying the Cost of Operation of Centrifugal Boiler and Feed Pumps," by A. C. Pasini and E. M. Spencer, revised by J. R. Hamann, Detroit Edison Co., Detroit.*

THE boiler feed pumps of a power plant are among the largest consumers of auxiliary power in the plant, hence knowledge that they are performing efficiently is of prime importance in plant operations. The efficiency of a high-pressure centrifugal pump decreases with continual use, from leaks resulting from erosion and wear.

A method of periodic testing has been developed to obtain data necessary to study decreasing efficiency and its associated increased power consumption. Results of the mathematical study have been extended to include a method of determining the most economical time to overhaul a pump.

The method of computing optimum time for repairs is not necessarily a general solution to the problem, but can be used if the conditions of a particular case fit the assumptions made.

Dimensional analysis is utilized to correlate data taken at different operating conditions to arbitrary standard conditions, $\pi_1$ and $\pi_2$, wherein $\pi_1 = Q/Nd^3$ and $\pi_2 = [P/(\rho N^2 d^2)]\pi_1$ represents the first pump law (flow, $Q$, varies directly as the speed, $N$, and cube of impeller diameter, $d$, for geometrically similar pumps) and $\pi_2$ the second law (total head, $P$, varies directly as the speed squared, water density, $\rho$, and impeller diameter squared, for geometrically similar pumps.)

Since $\pi_1$ and $\pi_2$ are independent and dimensionless, $\pi_2$ plotted against $\pi_1$ at a constant Reynolds number will completely describe the flow characteristics of a pump, such as Fig. 7. One such curve is generally sufficient. Variations of the test points from the design curve of $\pi_2$ vs. $\pi_1$ are considered entirely due to leakage. The design curve of $\pi_2$ vs. $\pi_1$ is based on a certain "leakage constant," which is mathematically defined as the design flow less test flow divided by the square root of the total pressure rise through the pump.

The pumps under consideration are direct-driven by 550 hp. AC motors of the wound-rotor, slip-ring, induction type, speed regulated by varying secondary circuit resistance. Power output is a function of both power input and speed. Testing is quite simple: motor input is measured by an integrating wattmeter, flow by an integrating venturi meter, suction and discharge pressures by Bourdon-tube gages, water temperatures by thermocouple and pump speed by mechanical tachometer. From these data, "leakage constant," efficiency with design and test leakage, and a calculation of pump speed and power required are made.

To determine mathematically the optimum time for repairs, the cumulative cost of power required to operate the pump is plotted against time over its entire life, Fig. 8, and is a straight-line function. Re-machining the casing and replacing certain wearing parts are stated by the pump manufacturer to restore the pump to original efficiency. If cost of power and repairs during the life of a pump be plotted against time, the slope of a line plotted from origin to end of pump life is the average cost of operation, and for minimum total cost the slope must be a minimum. The equation representing this optimum overall time in hours, $T$, is:

$$T = \left[\frac{K_2/K_1}{109{,}500} - \sqrt{\frac{(K_2/K_1)^2}{(109{,}500)^2} + 8b\frac{K_2}{K_1}}\right] + (-2b)$$

where

$K_1$ = cost of power to operate pump, \$ per Kwh.,

$K_2$ = cost of overhauling pump, \$,

$b$ = a constant, determined by plotting pump power input vs. time, Fig. 8,

109,200 = assumed life of pump, hours (90% operation for 20 years and 70% for ten years).

# Suggestions Given for Fabrication of Pressure Vessels from Stainless Alloys

*"Fabrication Notes on Corrosion-Resistant Alloys," by J. C. Holmberg, Alloy Welding & Mfg. Co., Tulsa (formerly Tulsa Boiler & Machinery Co., Tulsa)*

DISCUSSION of some of the problems presented in fabrication of pressure vessels from the six austenitic and three ferritic grades of stainless steels ordinarily used in this service are presented.

The three straight chromium grades (Types 410, 430 and 446) have excellent corrosion resistance to oxidizing agents and good heat resisting properties, are widely used in nitric acid service and for furnace parts. Any heating operation above 1500° F., however, has a tendency to cause severe grain growth and resultant embrittlement after cooling.

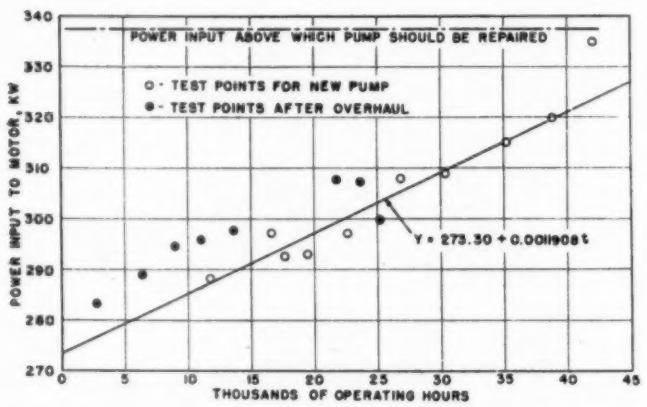
POWER INPUT ABOVE WHICH PUMP SHOULD BE REPAIRED
○ - TEST POINTS FOR NEW PUMP
● - TEST POINTS AFTER OVERHAUL
Y = 273.30 + 0.0011908 t
POWER INPUT TO MOTOR, KW
THOUSANDS OF OPERATING HOURS

Fig. 7—Plot of $\pi_2$ vs. $\pi_1$, showing design characteristics of a seven-stage centrifugal pump

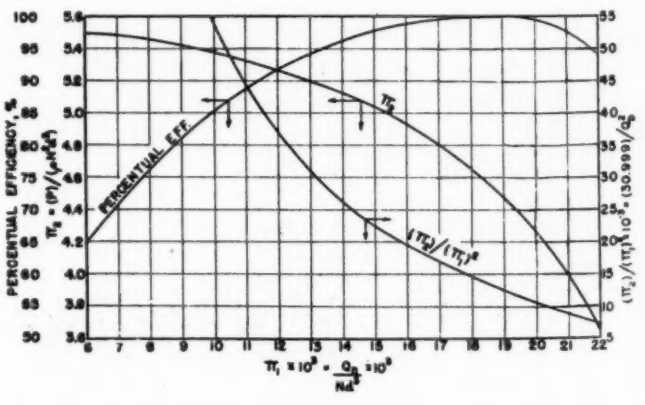


Fig. 8—Sample curve of power input to pump motor at standard conditions, constant quantity and head

For this reason these steels are rarely riveted and for welding it is usually recommended that an austenitic electrode be used to provide a more ductile jointure.

Type 430, a low carbon iron with 15-16% Cr, is the most popular for pressure vessel fabrication. It must never be cold-worked, rather preheated to 200-300° F. In hot-working, heating to over 1850° F. must be avoided and work should be on the die before it has cooled below 1500° F., at which temperature spinning or pressing should start. Edge preparation must be performed with care to minimize a tendency to tear.

Any hot work must be followed by an anneal, consisting of slow heating to 1450-1475° F., maintained there for two to three hours per inch of thickness, followed by slow furnace cooling and equalizing to 1100° F. Subsequent air-cooling as rapidly as possible is recommended.

Annealing should be followed by sand blasting and pickling in a solution usually consisting of 20% hydrochloric, 5% nitric, 5% sulfuric acids and 70% water for 20-30 min. After thorough scrubbing, a passivating treatment in 15-20% nitric acid follows.

In the austenitic grades there are three general classifications: an alloy containing 18-20% Cr and 8-10% Ni; the same, plus 2-3% Mo, and the stabilized grades containing either titanium or columbium. Practically, all have about the same physical properties in the annealed condition, possess good welding properties, are hard to machine and will cold-work to a marked degree.

Of these, Type 304 is the most widely used, contains 0.08% C, maximum, 18-20% Cr, 8-10% Ni. To this has been added molybdenum to produce a more stable alloy especially in the presence of chlorides and sulfites. This alloy has the undesirable characteristic of carbide precipitation when heated in the range 1100-1500° F. and it is in such areas that corrosion strikes first. The only remedy is to heat to 1950-2100° F., followed by rapid cooling or water quenching.

To overcome carbide precipitation, the stabilized alloys were developed. In these, titanium at the rate of four times the carbon, or columbium at ten times the carbon, is added during the melting process. This is a big improvement, but carries with it the penalty of increased cost.

For the successful utilization of any of the stainless alloys, it is of greatest advantage to fabricator, user, and steel manufacturer for the purchaser *not* to specify just "stainless steel." With more than 260 alloys considered as "stainless steels," plus a multitude of finishes and other contingent factors to consider, it is impossible for the fabricator to make an intelligent quotation on such a loose specification.

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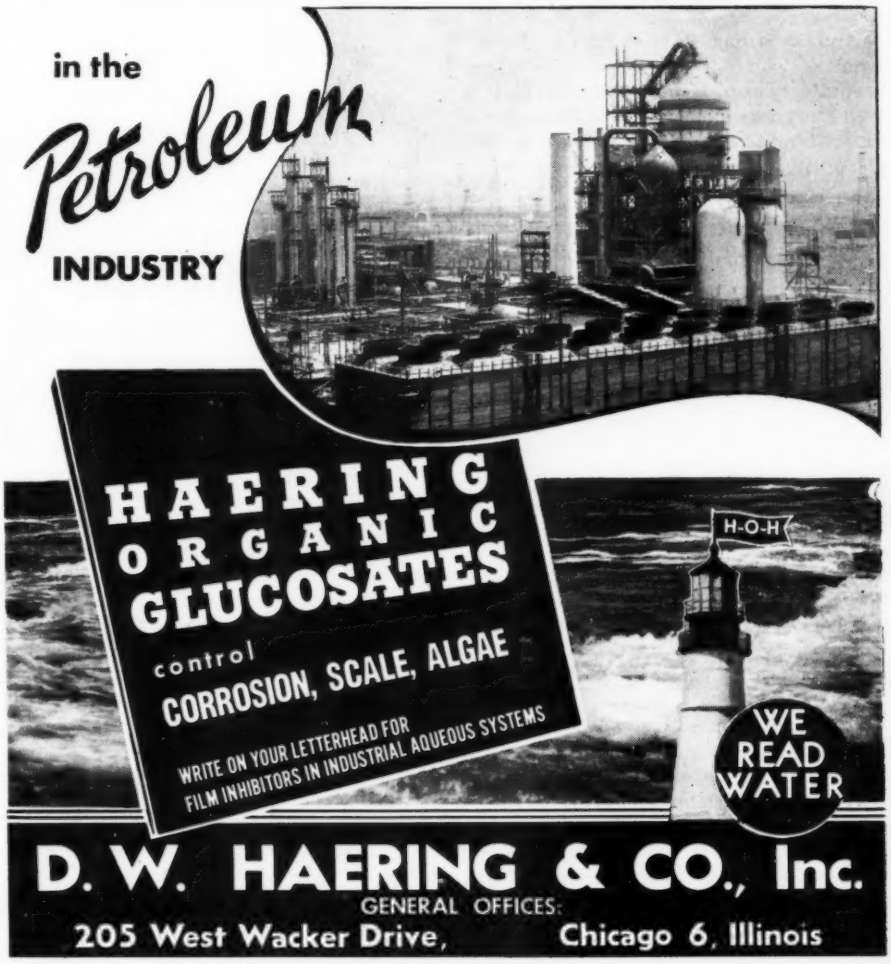


Copies of all books reviewed here may be ordered from the Reader's Service Department, Petroleum Processing, 1213 West Third St., Cleveland 13, for the prices listed, postpaid, unless indicated otherwise. Ohio purchasers please add 3% tax.

"Helpful Trade Literature" items are usually available without charge, and can also be secured from the Reader's Service Department of Petroleum Processing.

## Novel Approach to Explaining Chemistry in Book by Strong

*Chemistry for the Executive*, by Ralph K. Strong, 5¾ x 9 in., 445 pages, illustrated, indexed, stiff cloth binding, $6.00 (Dec., 1946).

*Chemistry for the Executive* presents a novel approach to the task of clarifying the fundamentals of the modern chemical industry for the busy, non-technically trained businessman, and it does it in an interesting and highly readable style.

Written as a series of interviews between the Mr. Executive and his chemist, Mr. Chemmer, the book covers in a concise manner the entire field of industrial chemistry. Each chapter represents a single interview between the two men, with the executive posing logical questions on the subject under discussion.

The book follows a pattern somewhat similar in nature to the average beginning text for the college or high school chemistry student. The 17 chapters, or interviews, begin with the elements, pass on through acids, bases, oxides, chemical reactions, solutions, liquids, solids, and colloids to a lengthy section—three chapters—on organic materials.

The last portion then deals with foods, fuels, metals, and synthetics, while the final chapter discusses a topic that could well be inserted in any freshman chemistry course—the economics of the industry.

Author Strong is head of the department of chemistry at Rose Polytechnic Institute, Terre Haute, Indiana, and is well-known as a chemical educator. He is also editor of Kingzett's "Chemical Encyclopedia," now in its seventh edition.

## Synthetic Rubber from Butadiene Is Subject of "Butalastics" Book

*Butalastic Polymers—A Treatise on Synthetic Rubbers*, by Frederick Marchionna, 6 x 8½ in., 642 pages, indexed, stiff cloth binding, $8.50 (Oct., 1946).

*Butalastic Polymers* describes and discusses from a strictly technical viewpoint the "elastic or plastic polymers of a butadiene compound, with or without other compounds polymerizable with it."

In the words of the author, the book was "written for the purpose of making available to scientists, research organizations, inventors, and manufacturers the extensive data on the production, properties, and uses of the various known butalastics, which are acquiring more and greater importance in national and international economics, relations, and social intercourse."

Presented in the volume are the history of the development of butalastics; the source and production of the raw materials used for forming them; the mechanism of polymerization; the methods of polymerization and copolymerization or inter-polymerization of the various compounds; the compounding practice, industrial application, and cure of the polymers; the properties and testing of the products; the reclaiming of butalastics waste; and derivatives of the butalastics.

The author, Frederick Marchionna, is an examiner in the U. S. Patent Office.

## Fourth in Hydrocarbon Physical Constants Series Published

*Physical Constants of Hydrocarbons*, Vol. IV, Polynuclear Aromatic Hydrocarbons, Gustav Egloff, 6 x 9 in., 540 pages, stiff cloth binding, $17.50.

With this newest volume on the polynuclear aromatic hydrocarbons, the series of American Chemical Society Monographs on *Physical Constants of Hydrocarbons* now includes four volumes. Aliphatic and alicyclic hydrocarbons were covered in Vols. I and II, while Vol. III, published last fall, covered the mononuclear aromatics.

The compounds included in the present volume are fused ring hydrocarbons having at least one aromatic ring. Although thousands of polynuclears have been prepared, these compounds represent only a minor fraction of the theoretical possibilities.

The present study also shows that the published data for many of the known compounds are insufficient for the identification of these compounds on the basis of physical properties alone. Critical evaluation of the data was limited by the scarcity of data available from the literature. For example, melting ranges of over 2° and boiling ranges greater than 5° have been recorded, because they were the only ones available.

In addition to other omissions, it will be noted that boiling point, density, and refractive index values have been determined for only a very few polynuclears. It is obvious that the opportunities for research on this type of aromatic is far from being exhausted.

Editor Gustav Egloff, who has handled the previous volumes in the series, is Director of Research for Universal Oil Products Co.

## New Book Discusses Effect of Public Policy on Oil Industry

*The Economics of the Pacific Coast Petroleum Industry*, Part 3: Public Policy Toward Competition and Pricing, by Joe S. Bain, 5⅞ x 9¼ in., 130 pages, indexed, stiff cloth binding, $3.00.

The third and concluding part in the series on *The Economics of the Pacific Coast Petroleum Industry* deals with the issues of public policy in the industry. It is essentially an essay developing a positive approach toward present and future regulatory problems.

The aim of the author is to arrive at positive suggestions regarding the degree and the kind of government regulation of industry which would most effectively help private enterprise to serve consumer interest. The work began with the two preceding parts in the series, Part 1, Market Structure, published in 1944, and Part 2, Price Behavior and Competition, published in 1945.

The present essay develops directly from Part 2, considering what policy issues were brought forth, how past prices have affected the welfare of the consumer, and what changes should be made.

Of interest is the author's method of handling disputable points. While retaining his own opinions and predictions, he recognizes that country views may turn out to have greater merit. Therefore, at several junctures in the text, the meat of differing opinions is included in the form of extensive but concise footnotes.

Dr. Bain is Professor of Economics at the University of California and is author of all three books in this series.

## Symposium on Bearing Tests Given in New ASTM Booklet

*Symposium on Testing of Bearings*, 6 x 9 in., 72 pages, heavy paper binding, illustrated, $1.50.

Five technical papers presented at the 49th Annual Meeting of the American Society for Testing Materials at Buffalo June 24-28, 1946, are collected here in booklet form. Subject matter includes life testing of plain bearings for automotive engines, fatigue testing machines for ball and roller bearings, metallographic observation of ball bearing fatigue phenomena, and testing of bearings under controlled loads.

## Helpful Trade Literature

A wall chart presenting condensed but complete information on the "Paramins," lubricant and fuel additives of Enjay Co., Inc., formerly Chemical Products Dept., Stanco Distributors Inc., has been issued by that company. For the line of 16 ad-

ditive improvers for premium and heavy-duty motor oils, aviation oils, industrial specialties and gasoline, the chart gives for the individual compound the active component, its properties, applications and miscellaneous data on compounding, storage and handling, etc. Copies of the "Paramins" wall chart are available to refiners and compounders, in line with the Enjay Co.'s policy of marketing these products only to concerns understanding and appreciating the functions of additive products. Enjay Co., Inc., 26 Broadway, New York City.

*Hot Process Water Softeners,* Publication 3000, a new 68-page bulletin containing an appendix dealing with feedwater chemistry, in addition to heat balances, flow diagrams, construction drawings of deaerating and non-deaerating softeners, and engineering tables and charts. Various types of installations are diagrammed and illustrated. Silica removal, sludge recirculation, automatic desludging, two-stage operation, and other recent technological advances are described. Cochrane Corp., 17th and Allegheny, Philadelphia 32, Pa.

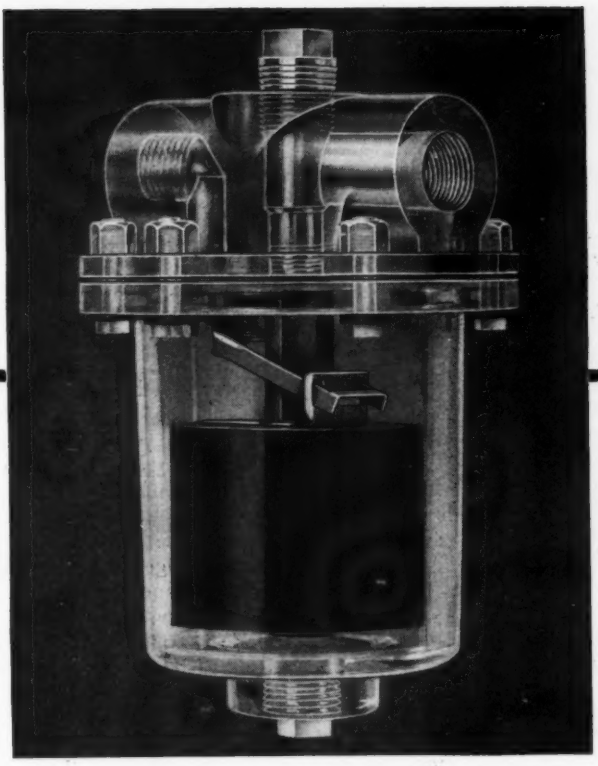
*Maintenance Hints for General Purpose Turbines,* B-3747, is a 95-page booklet containing practical information for the proper maintenance of general purpose turbines. It describes the steam turbine, explains its operation and installation. Dismantling and repair and adjustment information is given. A final chapter deals with emergency hints for quick reference. Westinghouse Electric Corp., P.O. Box 868, Pittsburgh 30, Pa.

*Learning to Weld,* a 32-page booklet, illustrations include photographs and drawings. It provides a simple basic approach to anyone interested in making a start in arc welding. Also included are conversion tables on decimal equivalents and thicknesses of metal in both gage and inches, as well as a glossary of welding terms. Copies 25c each, postage prepaid, The Lincoln Electric Co., Cleveland 1, Ohio.

*Prescription for Glycerides,* describes the application of the Solexol process of "cold fractionation" of vegetable, animal, and marine oils by the use of propane. The M. W. Kellogg Co., 225 Broadway, New York 7, N. Y.

### Fractional Distillation

The seventh in the series of articles on fractional distillation by Robert R. White and his associates at the University of Michigan has been omitted from this issue because of space limitations. It is entitled "Elements of Ternary Distillation" and will appear in the May issue of PETROLEUM PROCESSING.

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PERSONALS

# Petroleum Technologists in the Headlines

**Dr. C. L. Brown** has resigned as director of the Esso Laboratories of the Standard Oil Co. of New Jersey, Louisiana Division, Baton Rouge, to become a member of the research and development coordination group of the Standard Oil Development Co. He will assume the coordination work in the chemical field and the exploratory research in all fields. For the present he will make his headquarters at 30 Rockefeller Plaza, New York City.

Dr. Brown

Replacing Dr. Brown is **A. Voorhies, Jr.**, who has been appointed director of Esso Laboratories, Louisiana division, for Jersey Standard. In addition to this appointment **Dr. R. W. Richardson** has become associate director of Esso Laboratories, and **Dr. R. W. Krebs** has been made assistant director. Associated with Dr. Krebs are assistant directors, **C. E. Starr, Jr.**, and **L. E. Carlsmith.**

* * *

**Clarence H. Thayer,** chief engineer for the Sun Oil Co. at Philadelphia, was elected a vice president of the company at a recent meeting of the board of directors.

Mr. Thayer

Mr. Thayer was selected in 1940 as one of the 18 inventors out of the 500 elected by the National Association of Manufacturers to be honored as a "Modern Pioneer on the Frontier of Industry" and was presented a "Pioneers Certificate" for making possible the commercial installation of Houdry Catalytic Cracking units. He holds other patents for apparatus and methods of processing gasoline.

He is also a director of the Catalytic Engineering and Construction Co.

* * *

**E. A. Timm** has retired as Safety Director for the Standard Oil Co. of New Jersey's Bayonne refinery. He has been with the company for over 25 years, and is a pioneer in the organized safety movement in the petroleum industry.

Mr. Timm became an Esso employe in the Bayonne refinery machine shop in 1902. His experience in mechanical work and enthusiastic devotion to accident prevention led to his appointment as director of the safety department when it was organized in 1920. In spite of many setbacks shared by the founders of the industrial safety movement Mr. Timm spearheaded an educational crusade inside and out of the plant selling both himself and safety to management and employe alike. Under his direction the accident frequency of the plant plunged from 36.0 in 1919 to 4.29 in 1945, one of the best records in the oil industry.

He is a member of the National Safety Council, Hudson County Safety Council, and the American Society of Safety Engineers.

* * *

**R. A. Findley** has been placed in charge of the chemical engineering pilot plant of the Phillips Petroleum Co. in Bartlesville, Okla.

* * *

**Guy S. Mitchell,** chief chemist of the Lion Oil Company, El Dorado, Ark., has been elected chairman of the Ark-La-Tex Section of the American Chemical Society. He succeeds **Dr. John B. Entrikin,** head of the science department of Centenary College, Shreveport, who was named to the Society's National Council.

Mr. Mitchell

**Dave N. Barrow,** assistant superintendent of the natural gasoline department of the Arkansas Fuel Oil Company, Shreveport, was chosen vice chairman, and **A. W. Trusty,** chief chemist of the same company, secretary-treasurer.

Three were made directors of the Section. They are: **James R. Cox,** president of the James R. Cox Company, Shreveport; **J. B. Leftwich,** chief chemist of the Silas Mason Company, Minden, La., and **Ruth Evans,** senior chemist of the Lion Oil Company.

Mr. Mitchell, a former chairman of the petroleum group of the Society's Oklahoma Section, was born in Richmond, Mo., on July 3, 1899. He received the B. S. degree in chemical engineering from the University of Oklahoma in 1921, the M.S. from the University of Kansas in 1923, and the Ch. E. from Oklahoma in 1925.

He joined Cosden and Company, Tulsa, as a chemist in 1922, and the next year became chief chemist of the Producers and Refiners Corporation, Parco, Wyo. From 1924 to 1942 he was on the staff of the Bareco Oil Company, Barnsdall, Okla., first as chemist and later as chief chemist. For the period 1922 to 1942 he was engaged primarily in work on petroleum refining.

Since 1942 he has been with the Lion Oil Company doing research in ammonia and ammonium nitrate.

* * *

**Dr. Clarence A. Nielson** has been transferred from the Baltimore refinery of Continental Oil Co. to the Ponca City, Okla. refinery,

* * *

The Independent Refiners' Association of California, Inc., at their 11th annual meeting have elected **C. A. Johnson,** Socal Oil & Refining Co., president, and have elected **D. B. O'Neill,** vice president and general manager, **M. M. McCallen,** McCallen Refining Co., vice president, and **Clifford Hancock,** Caminol Oil Co., secretary-treasurer.

Directors of the Association elected for a one year tenure were **B. E. Devere,** Pathfinder Petroleum Co., **D. S. Fletcher,** Fletcher Oil Co., **W. G. Krieger,** Douglas Oil Co. of Calif., and **J. D. Sterling,** Eagle Oil & Refining Co.

* * *

**Brig. Gen. James Creel Marshall** has been retained on the engineering staff of the M. W. Kellogg Co., Jersey City, N. J. He is widely known in engineering and construction circles through his 30 years of service on many major projects in peace and war.

Gen. Marshall

Foremost among General James Marshall's recent Army activities was his service with the Manhattan District project, charged with the development of the Atom bomb.

The General also served in the Southwest Pacific, Australia, New Guinea, and the Philippines. During the latter half of 1945 he commanded the Boston Port of Embarkation and in 1946 was made President of the Engineer Board, the research and development agency for the Corps of Engineers at Ft. Belvoir, Va.

Outstanding among the many diverse activities during the peacetime years, was his work as Area Engineer at Albany, N. Y. in charge of the $27,000,000 improvement project on the New York State Barge Canal.

## Personals

**George Reid** of Houston has been appointed Southwestern representative for PETROLEUM PROCESSING and *National Petroleum News*. His headquarters will be at 3401 Buffalo Drive, Houston.

**Mr. Reid**

Mr. Reid has been identified with the petroleum industry for 30 years. He left the University of Arkansas in 1916 after three years work majoring in chemistry. He spent 10 years working in refineries as chemist, chief chemist, assistant superintendent and superintendent.

For 12 years he was associated with the Gulf Publishing Co., Houston. He became editor of *The Petroleum Refiner* for that organization and a consultant to the sales department on refinery equipment, processes, and economic trends. He also edited a handbook and a composite catalog of oil refinery equipment published by that company.

In 1939 Mr. Reid joined the Gulf Coast Refiners Association as executive secretary and held that position until its disbandment in Jan. 1947.

* * *

**Dr. Frederic L. Matthews** has been appointed an associate director of research for Monsanto Chemical Co.'s Merrimac Division at Everett, Mass.

It was announced simultaneously that Dr. Matthews' former post of co-ordinator of petroleum additives in Monsanto's Organic Chemicals Division will be filled by **Harry W. Faust,** at present a group leader in petroleum chemical research in the division.

Mr. Faust's post will be filled by **Dr. J. F. Palmer,** a research chemist in the petroleum chemical research group.

* * *

**L. Earl Hoffman,** has been added to the staff of the Special Products division of Phillips Petroleum Co.'s Chemical Product Department at Bartlesville, Okla. He has been taking a refresher course at Iowa State University since his release from the military service in March of 1946.

* * *

**William L. Bolles** has left the research and development laboratories of Socony-Vacuum Oil Co., and is now a chemical engineer in the development department of Monsanto Chemical Co., St. Louis.

* * *

**Lewis K. Dalrymple,** who had been chief engineer of the Mid-Continent Division, Tide Water Associated Oil Co., Tulsa, has announced his retirement from the business.

* * *

**C. Leon Harrington** has been promoted to operating assistant at the Marcus Hook Refinery of Sun Oil Co. at Phila.

# CLASSIFIED

**Petroleum Processing announces this new classified section as a regular feature for the convenience of its readers. Classified rates are shown in the accompanying box.**

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WANTED — Chief Engineer for independent Oklahoma refinery. Must have engineering degree and experience in refinery corrosion and inspection procedures, general plant engineering maintenance and operation. Operating experience on crude topping, vacuum distillation, thermal cracking and product treating. Must not be over 40 years of age. Box 10.

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**EDITORIAL COMMENTS**

# WIDENING HORIZONS

## *Scientific Research and Development Is Multi-Billion Dollar Business*

INDUSTRY in this country this year is spending over a half billion dollars in research and development work and the government plans to spend at least double that amount in scientific research. Together these programs utilize the labor of about 400,000 workers, which is nearly one per cent of our manpower. Research devoted to hydrocarbons and their chemistry takes over $50,000,000 a year and employs about 10,000 people. The oil companies are by far the principal contributors in this field of research.

These impressive figures on the scope of research and development work in this country were presented by Dr. Monroe E. Spaght, vice president of Shell Development Co., in a recent address before the American section of the Society of Chemical Industry. Recognizing the indispensable position of the hydrocarbon industry today in supplying the needs of our people, Dr. Spaght proposes five aims for the research and development program in this field:

**1—To develop and maintain a supply of raw material.** Next to petroleum itself he notes that natural gas reserves nearly equal in weight the proved petroleum reserves. Provision of the means for converting gas to liquid fuels by the Fischer-Tropsch process represents a notable technical achievement, and greatly increases the strategic position of a nation with large gas reserves.

Looking far ahead to the time when coal may be called upon to supply the need for hydrocarbons, Dr. Spaght believes the cheapest way to produce liquid hydrocarbons from this material will be via a water gas reaction and subsequent synthesis by the Fischer-Tropsch reaction.

**2—To improve existing processes.** Wide possibilities for technical improvements exist here, it is pointed out, because of the chemical complexity of the mixtures with which the industry normally works and the fact that many of its processes produce more than a specific desired reaction, including a multiplicity of decomposition reactions at the high temperatures employed.

**3—To improve and find new uses for existing products.** The adaptation of existing products to ever changing requirements is a major and continuing problem in a nation geared to a high industrial tempo where new and more stringent demands are being made upon the suppliers of fuels and lubricants. Finding peacetime uses for some of the new hydrocarbon compounds developed during the war is an important field to explore, he points out.

**4—To develop new processes.** Improvement of separation techniques will be of great advantage to the hydrocarbon industry, Dr. Spaght brings out, where the separation of pure compounds and classes of compounds from mixtures is the most common task in processing operations. "Despite the great amount of attention that has been given this subject we still have the ability of effecting only the simplest separations" he states. When we pass beyond the range of about 8 carbon atoms the only practical method of obtaining a pure compound is by a synthesis from lower molecular weight elements.

Continuing, he points out that "A process to transform polynuclear aromatics into low boiling liquids without resorting to such a severe and costly decomposition as high pressure hydrogenation would solve the refiners' greatest need."

**5—To Develop New Products.** One prominent oil company today markets over 1000 products. Nevertheless the opportunities for new products from hydrocarbons are still almost unlimited, it is stated. It is certain that new compounds useful to the chemical industry will appear in increasing numbers from the hydrocarbon industry and it can also be expected that future demands for new types of fuels will present demands to the industry for new volume products.

Dr. Spaght's comments emphasize the importance of scientific research in the petroleum industry. They should be illuminating and inspiring both to the men actively engaged in this work and to the executives of the oil companies which invest the capital to carry it on. Truly no company activity today is more important than that of its research and development division.

## *Chemical Industry Looks to Petroleum For Many Plastics Raw Materials*

CHEMICAL manufacturers, especially those producing plastics, disinfectants and detergents, are turning to the oil industry to supply petrochemicals as raw materials to supplement and perhaps even supplant existing sources. Some pertinent figures come from a chemical manufacturer.

Right now there is a need for between 15 and 20,000,000 gal. of benzene. A part of the current shortage is directly attributable to the coal strike last fall, since most of the supply comes from coke ovens. The balance is due to the expanding market for this material as a component of styrene. Styrene is in strong demand for synthetic rubber and as polystyrene plastic. By 1950, if present estimates hold good for anticipated needs, 50,000,000 gal. in excess of foreseeable benzene supply will be required.

The chemical companies do not care whether their benzene comes from coal or oil; they require that it be of reasonably high purity, at least 90% and preferably higher, and with reasonable assurance of steady supply.

Naphthalene and cresylic acids likewise will continue in strong demand. The present gap between supply and market is estimated at 25,000,000 lbs. annually for each of these chemicals. Naphthalene first is converted to phthalic anhydride, whence it becomes an important component of plastics. Cresylic acid, too, is used largely in the manufacture of plastics (about 70% of production) and the balance in disinfectants.

The volume figures given above, it is true, are mere drops in the bucket when compared with those for most oil company products. However, they are impressive in the rates of increase shown, and in the words of the research director of a large chemical company, "all these needed chemicals could come from petroleum".

READERS' comments and opinions will be welcomed by the editors of PETROLEUM PROCESSING, 1213 West Third Street, Cleveland 13, Ohio

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**Sulfan 'C'** Unstabilized.

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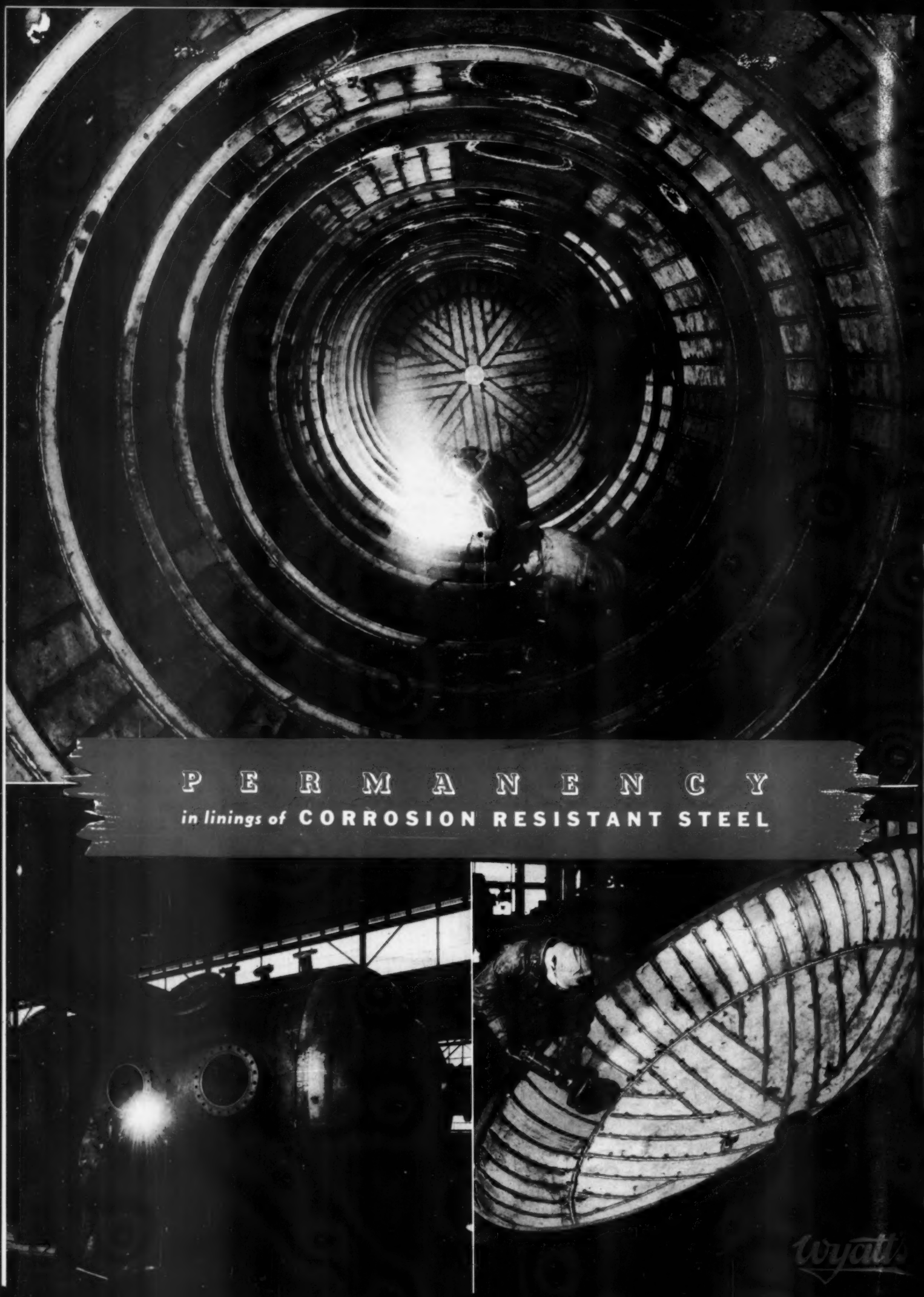
|---|---|---|---|
| Description | Ice-Like | Asbestos-Like | Asbestos-Like |
| Equilibrium | | | |
| Melting Point (°C): | 16.8 | 32.5 | 62.3 |
| Density (20°C) | 1.9255 | — | — |
| Sp. Ht. (cals/gm) (20°C) | 0.77 | — | — |
| Ht. of Fusion (cals/mol) | 1,800 | 2,900 | 6,200 |
| Ht. of Sublimation (cals/mol) | 11,900 | 13,000 | 16,300 |
| Ht. of Dilution (cals/mol) | 40,340 | — | — |
| Vapor Pressure (mm.) | | | |
| 0°C | 45 | 32 | 5.8 |
| 25 | 433 | 344 | 73 |
| 50 | 950 | 950 | 650 |
| 75 | 3,000 | 3,000 | 3,000 |

**GENERAL CHEMICAL COMPANY**

**40 RECTOR STREET, NEW YORK 6, N. Y.**

**Sales and Technical Service Offices in principal cities from coast to coast**

*Trade Mark, General Chemical Company


PERMANENCY
in linings of CORROSION RESISTANT STEEL
Wyatt's